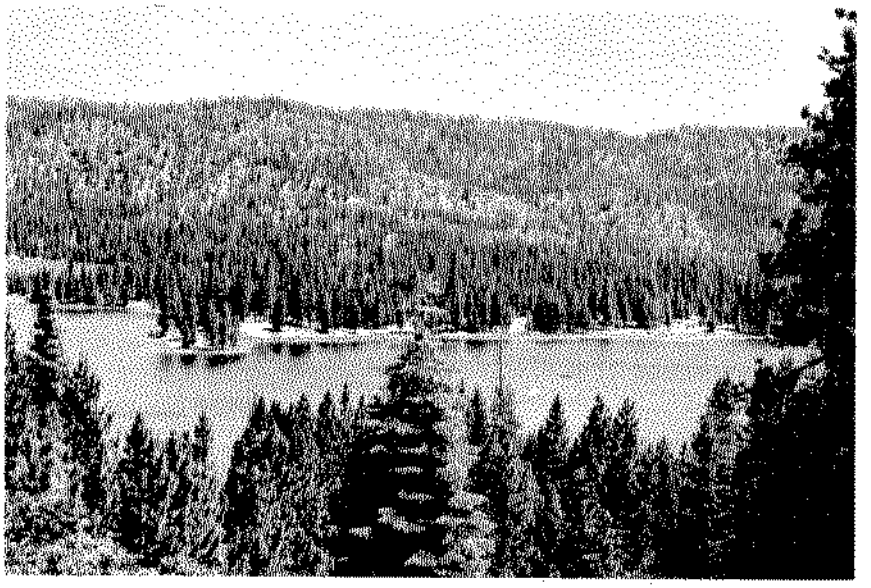
Evaluation of a Revised Operation for Antelope Reservoir



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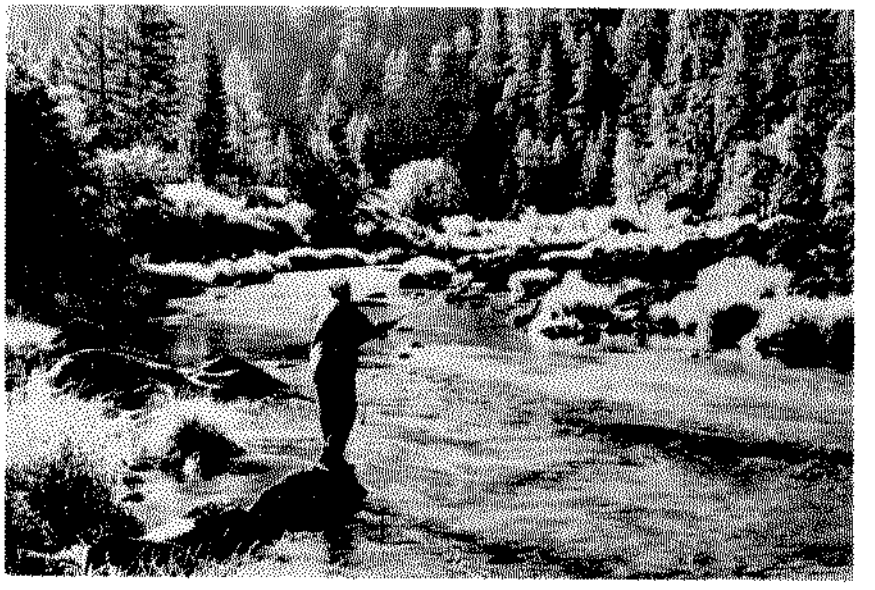

State of California The Resources Agency Department of Water Resources Northern District

FOREWORD

In 1975, the Department of Water Resources adopted a water management policy that included the concept, "Instream water uses for recreation, fish, wildlife, and related purposes shall be balanced with other uses". "Other uses", of course, meant mainly the normal water-supply uses. This new concept led to an Instream Water Use Program in the Department with the objective of finding opportunities to improve flows in streams for enhancement of streamside recreation, fish and wildlife habitat, aesthetic value, and riparian vegetation.

One opportunity identified by the program was the possibility of revising the operation of Antelope Reservoir, a part of the State Water Project, to increase summer flows in Indian Creek, a tributary of the East Branch North Fork Feather River. A revised operation was begun in March 1978, and the impact on Indian Creek and Antelope Reservoir was monitored for three years.

This report describes the monitoring program and the effects of the revised operation on Indian Creek and Antelope Reservoir, and recommends a future operation schedule for Antelope Reservoir.

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INTRODUCTION

This report summarizes studies by the California Departments of Water Resources (DWR) and Fish and Game (DFG) to evaluate the operation of Antelope Reservoir. The purpose of the evaluation was to determine if a revised operation of the reservoir could improve trout habitat and streamside recreation in Indian Creek, with a minimal effect on Antelope Reservoir recreation.

We discuss three operating schedules for the reservoir. The "original" schedule prevailed from the time the reservoir was completed until 1978. The "revised" schedule was used the past three years to make this study, and we recommend that it be continued. A "possible alternative" schedule will be discussed but not recommended for use.

The original schedule provided flows of 0.56 m^3/s from April through June and 0.28 m^3/s for the rest of the year. The revised schedule maintains 0.56 m^3/s year-round unless, as with the other schedules, reductions in flow are necessary in dry years. A possible alternative of 0.85 m^3/s year-round is rejected because of undesirable effects on Antelope Lake. To varying degrees, all of these flows benefit fish in Indian Creek, because the pre-project summer flows were too low to support a sizable fishery.

Antelope Reservoir is one of three upper Feather River reservoirs built as part of the State Water Project. It was completed in December 1963 and became operational in 1964. It has two primary purposes, reservoir recreation and downstream fisheries enhancement.

In 1976, DWR identified several streams that might benefit from the Instream Flow Program (DWR, 1979). Indian Creek provided an ideal opportunity for streamflow enhancement because Antelope Reservoir is a unit of the State Water Project, its inflow greatly exceeds the scheduled release, and water rights agreements relating to the project require that water releases from storage be used only for downstream flow enhancement.

If fishing and other streamside recreation along Indian Creek can be increased without significant impact on Antelope Reservoir recreation, the recreation opportunities in the Plumas National Forest would be enhanced. Stream trout fishing is high quality, specialized recreation, generally declining in availability. The U. S. Forest Service (USFS) encourages dispersed recreation of this type to minimize the impact of increasing use on forest recreation lands.

Photo, opposite--Indian Falls, a few miles above the mouth of Indian Creek, is one of the loveliest spots along the creek. It is a favorite with recreationists.

CONCLUSIONS

1. Recreation use at Antelope Reservoir and downstream along Indian Creek far exceeds the use levels estimated when the reservoir was built. Reservoir recreation is reported to be about three times the predicted 1980 level, and Indian Creek recreation is about 30 percent higher than was forecast.

2. The original reservoir operation provided flows in Indian Creek more than three times the pre-project late summer flows (0.28 m^3/s versus about 0.085 m^3/s). This flow schedule increased trout habitat in upper Indian Creek about five times over pre-project conditions with a corresponding increase in trout populations.

3. A proposed further increase in the mid-summer, fall, and winter release from 0.28 to 0.56 m^3/s roughly doubles trout habitat in upper Indian Creek from the existing levels.

4. Data collected during a three-year trial of this revised operation indicate trout populations in upper Indian Creek are increasing due to the higher flow. Fishing use and quality should begin to increase as anglers discover the larger trout populations.

5. Higher flows in Indian Creek seem to attract more fishing use for subjective reasons related to the appearance of the stream. Anglers associate higher flows with better fishing and know that reservoir spills allow rainbow trout to leave Antelope Reservoir and enter Indian Creek. The catch of both rainbow trout and brown trout increases with streamflow up to 2.3 m^3/s.

6. In addition to downstream fishery and recreation enhancement, the revised operation schedule provides minor increases in hydroelectric energy production and water supply to Oroville Reservoir. It also slightly reduces spill from Antelope Reservoir in some years.

7. Potential detriments of the proposed revised operation include minor decreases in aesthetic quality of the reservoir recreation, slightly more difficult access to the lake shore and boat ramp, and a slight reduction in mid-summer water surface and reservoir fish production. None of these impacts is considered important for the proposed operation schedule.

8. The proposed operation schedule did not measurably affect recreation use or fishing success on Antelope Reservoir during the three-year study period.

9. A possible alternative operation schedule providing a release of 0.85 m^3/s year-long to Indian Creek could further increase downstream benefits, but would have greater negative impacts on Antelope Reservoir.

10. The February 1 forecast of runoff conditions can be used to reduce the reservoir release in exceptionally dry years (less than 50 percent of normal), thus avoiding several months of higher winter and spring flows that would cause low water levels in Antelope Reservoir the following summer.

11. Water quality conditions in Indian Creek below Antelope Dam are satisfactory for trout production with both the original operation schedule and the proposed schedule. In late summer the first 3 km of stream below the dam has an unpleasant odor and a reddish appearance caused by the precipitation of iron from water released from lower depths of Antelope Reservoir. These conditions do not seem to affect trout production in the stream, but are aesthetically displeasing to recreationists for the last two months of summer in most years.

RECOMMENDATIONS

1. The operation and maintenance manual for Antelope Reservoir should be revised to provide a downstream release of 0.56 m^3/s year-long with reductions to 0.28 or 0.14 m^3/s in dry years when the reservoir does not fill by June 1 (Appendix B, Table 2).

2. The February 1 forecast of runoff from the drainage above Antelope Reservoir should be used to predict runoff conditions. Downstream releases should be reduced in early February during years when the expected runoff is less than 50 percent of normal or when it appears the reservoir will not fill by June 1. The lower release would continue until the reservoir is forecast to fill.

3. A revised Use Permit should be obtained from the U. S. Forest Service for the operation of Antelope Reservoir. It should reflect the new operating criteria, including the dry year reductions.

4. Fish populations and related fishing use in upper Indian Creek should be monitored in 1981 and 1982 to document changes now occurring.

5. DFG should try to manage the Antelope Reservoir fishery so as to reduce the need for draining to remove non-game species.

Photo opposite--Antelope Dam and Reservoir, Plumas County.

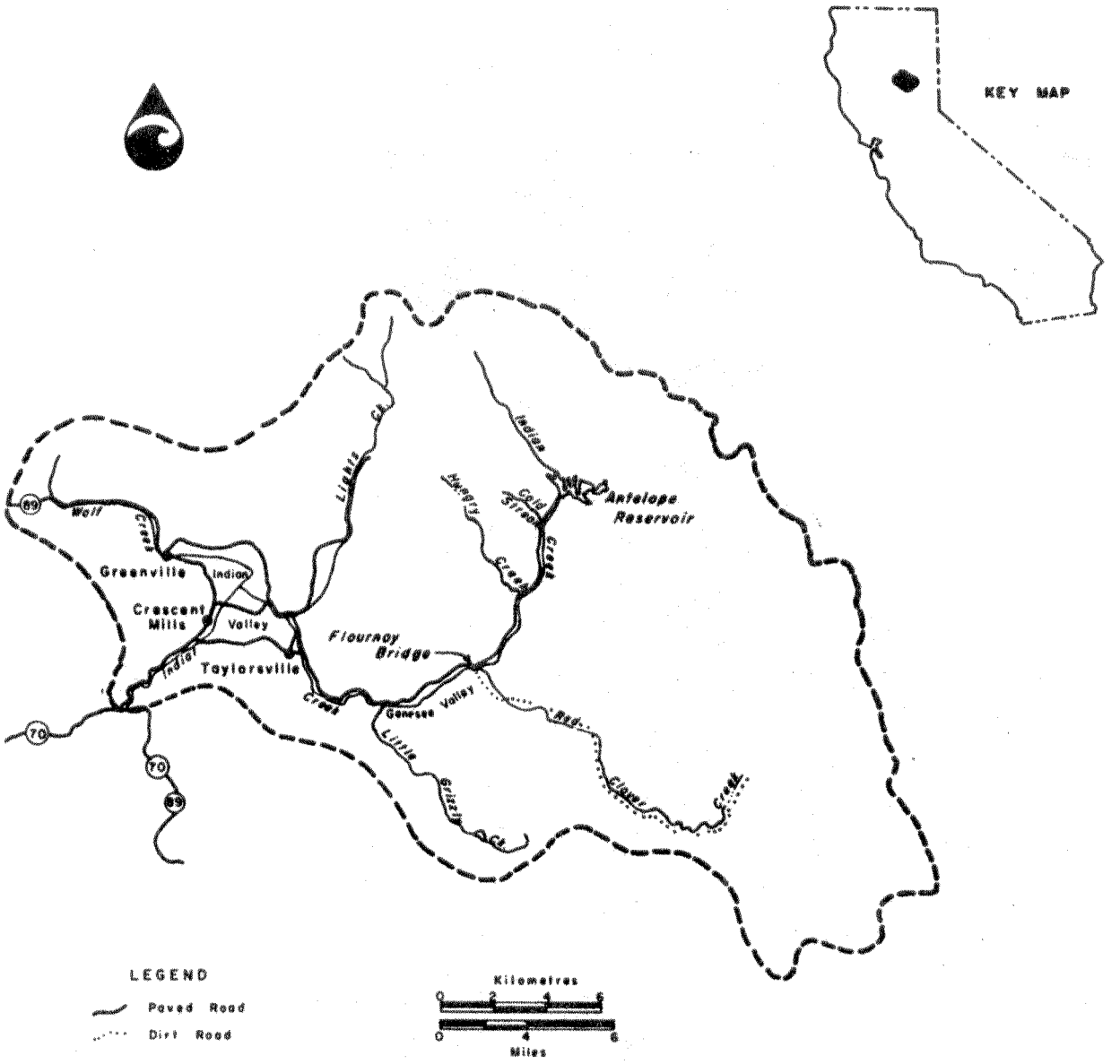


Figure 1 – Antelope Reservoir and Indian Creek, Plumas County, 1981.

DESCRIPTION OF STUDY AREA

Indian Creek is a major tributary of the East Branch North Fork Feather River (Figure 1). Below Antelope Reservoir, Indian Creek flows rapidly through a steep, forested canyon to its confluence with Red Clover Creek. Here, Indian Creek enters Genesee Valley and meanders several miles through large ranches. It then enters another open-forested canyon for several miles and then flows through Indian Valley near Taylorsville. Indian Valley is used heavily for cattle grazing, and the creek is extensively diverted for irrigation of pasture lands. It finally enters a spectacular gorge along State Highway 89 and cascades down to its confluence with Spanish Creek.

Before construction of Antelope Reservoir, Indian Creek had high spring and early summer flows (1.4 m^3/s and above) and flows less than 0.3 m^3/s the rest of the year. Minimum flows averaged about 0.1 m^3/s. Average annual runoff at Antelope Dam is about 46 600 dam^3. The reservoir has a storage capacity of 27 835 dam^3 at a normal water surface elevation of 1 524.6 m. The summers are warm and dry, with most of the precipitation as snow in winter. Precipitation varies from 40 to 200 cm annually.

PROJECT HISTORY

Historically, Indian Creek was considered to be a rainbow trout stream. However, fish population surveys made by DFG as early as 1962 indicated that both rainbow and brown trout were present, with brown trout usually dominant (Gerstung, 1973, and unpublished data). It was planted with fingerling and catchable-sized rainbow trout annually between 1950 and 1955, then with only catchable-sized trout through 1963. One small plant of eastern brook trout was reported in 1963. Plants of fingerling brown trout were made in 1967 and 1973 (Appendix E).

A creel census in 1955 on lower Indian Creek, from Crescent Mills to the mouth, showed limited use. About the same time, the upper reaches of the stream, above Hungry Creek, became popular for recreation. As construction of Antelope Dam began in 1962, DFG assessed the proposed operation schedule for the reservoir. A creel census on lower Indian Creek showed a marked increase in the recreation use of the creek since 1955.

DFG biologists measured several transects to evaluate stream depth, spawning, and food production over a range of streamflow conditions. Information from these studies, historic streamflow conditions in the area, and DFG's knowledge of the stream fishery were used to formulate the instream flow release schedule for the reservoir (Jones and Stokes Associates, 1976).

DFG and DWR agreed on a flow release schedule from Antelope Dam, which was approved by the USFS and U. S. Fish and Wildlife Service (USFWS). DFG recommended flows of 0.56 m^3/s during the spring spawning months and 0.28 m^3/s the rest of the year in Indian Creek from the dam downstream to Genesee Valley. The flow release provided higher flows during the spring months to maximize the spawning potential for (rainbow) trout. Lower flows could be maintained the rest of the year if they provided adequate habitat to maintain trout populations. Releases were reduced during years when the reservoir was not full on May 1. Apparently brown trout spawning in October and November was not considered.

The effects of these releases on reservoir recreation and the downstream fishery were to be observed for a five-year period and the release schedule modified if necessary (DWR, 1962). Unfortunately, files of DFG and DWR do not contain any record of the data used to determine the instream flow release schedule adopted for Antelope Reservoir, suggesting it may have been based largely on judgment.

Fish population studies conducted before construction of Antelope Valley Dam showed the creek supported about 9 kilograms of trout per hectare (kg per ha). In 1968, after four years of project operation, the trout population had increased to about 48 kg per ha (Gerstung, 1973). This is about average for northern Sierra trout streams. Planted catchable trout were not included in these estimates; none was stocked after 1963, but data for most of these estimates have been lost, so they cannot be verified.

Antelope Reservoir was completed in 1963, and it has been managed as a trout fishery based on annual plants of 200,000 to 250,000 rainbow trout fingerlings. These grow rapidly and reach catchable size by the following season. The reservoir is capable of producing 45 to 55 kg per ha of trout when competing species are absent. When competing species are numerous, fingerling trout survival and growth is depressed and the lake must be managed with catchable trout. Competing species have been a serious problem almost from the start. Golden shiner and brown bullhead were

numerous by 1968. The reservoir was drained in 1971 and again in 1976 and treated with rotenone to remove the non-game fishes. As the reservoir refilled it was restocked with fingerling and subcatchable rainbow trout. This management policy requires draining and chemical treatment about every five years.

In late 1980, DFG proposed to manage Antelope Reservoir with a combination fishery: trout, largemouth bass, and channel catfish. This was to try non-chemical control of the unwanted fish, thus avoiding the need to drain the reservoir every five years. The effort was approved by Plumas County officials, USFS, and DWR, and catfish and bass were planted in winter 1980-81.

RUNOFF DURING THE STUDY PERIOD

This study was conducted during several relatively dry years, and so was a good test of the proposed release schedule under poor runoff conditions. Antelope Reservoir was drained in fall 1976 so it could be chemically treated to remove non-game fish. The winter of 1976-77 was extremely dry (10 percent of median runoff) and Antelope Reservoir did not refill until May 1978. The release from Antelope Dam was near zero until late April 1977, then ranged from 0.28 m^3/s to 0.03 m^3/s during the summer and fall. Several small tributaries added flow a short distance downstream. The revised flow schedule (0.56 m^3/s year-round) began March 15, 1978, when a large snowpack made it obvious Antelope Reservoir would fill. This release continued until January 17, 1979, when a very small snowpack and predictions of a dry spring (about 39 percent of median runoff) suggested the release should be reduced to 0.28 m^3/s to ensure the filling of Antelope Reservoir. The reservoir filled and spilled briefly in late May and early June 1979. The 0.28 m^3/s release continued through the fall until large storms in December 1979 and January 1980 filled the reservoir and started a long period of spill from mid-January to early July 1980. When the spill ended, the release was continued at 0.56 m^3/s until late January 1981, when an unusually low snowpack and predictions of a dry spring again suggested reduction to 0.28 m^3/s was necessary to fill the reservoir.

SCOPE OF STUDIES

This report summarizes a three-year (1978-1980) monitoring program of Antelope Reservoir and Indian Creek. Specific studies included: (1) streamflow studies on Indian Creek to determine the effects of various flows on trout habitat; (2) fish population surveys in the upper creek each fall to determine the number, ages, size, and weight of fish in sample sections of the creek; (3) recreation surveys on the creek to determine recreation use levels, activities, visitor origin, and other characteristics of streamside use; (4) a creel census on the creek and reservoir to determine the amount of fishing use, catch, and species caught; and (5) water quality samples to monitor temperatures, pH, turbidity, and electrical conductivity.

A limited recreation survey was conducted in 1977 to develop methodology for the three-year evaluation. Fish populations were sampled in October of that year to provide baseline data for the three-year study.

Details of all these studies are available in a series of DWR Technical Information Reports and DFG Information Reports (see "References"). The scope of the studies is briefly described here.

Streamflow Study

A streamflow study was conducted on Indian Creek in fall 1976 to determine the effects of various flows on trout habitat. Two methods of streamflow evaluation were used: an unweighted method used by USFWS (1976) on a Tuolumne River flow study, and a weighted method described by Waters (1976). Available trout habitat was determined at two locations for flows between 0.05 m^3/s and 3.0 m^3/s (Study Area 1---about 12 km below Antelope Dam) and 0.6 m^3/s to 3.1 m^3/s (Study Area 2---just above Flournoy Bridge). Operation studies also were prepared to determine the effects of several potential flow schedules on Indian Creek and Antelope Reservoir.

Fish Population Surveys

Fish populations were monitored by DFG from 1978 to 1980. The creek was sampled at six permanent study sections each fall to determine the abundance and biomass of each species. Coefficient of condition (robustness), percent of age groups, length-weight relationships, and growth rates were

also calculated. The study sections were near locations previously sampled by DFG. They were chosen to represent various types of trout habitat, but were probably not representative of the entire stream. The release from Antelope Reservoir was reduced to 0.14 m^3/s for 5 days each year to make fish sampling easier.

Recreation Surveys

Recreation surveys were conducted from 1978 to 1980 during the trout season. A random sample survey was taken along distinct stream reaches and during different use periods. Roving use counts and interviews gave information on use levels, activities, length of stay, visitor origin, and other data. Total estimated recreation hours, types of activities, mean length of stay, and mean number of people per vehicle were determined. Estimates of recreation use on Antelope Reservoir were obtained from the USFS.

Creel Census

Creel censuses were conducted from 1978 to 1980 during the trout season. Each angler was asked for county of residence and length of time fished. Fish caught were counted, identified by species, and measured. Total hours fished, number of each species caught, and average length of fish were determined. Estimated hours fished and estimated number and weight of fish caught were calculated. A creel census also was conducted on Antelope Reservoir to monitor fishing success. In 1979, total fishing use and catch on Antelope Reservoir was also determined.

Water Quality Samples

Water samples were taken in 1978 to 1980 in conjunction with the recreation survey and later tested for pH, turbidity, and electrical conductivity. Water and air temperatures also were recorded. Only water and air temperatures were recorded in 1977 during the preliminary survey. Baseline surveys of water quality conditions in Antelope Reservoir, Indian Creek, and Little Grizzly Creek were also conducted by DWR in September 1979.

RESULTS AND DISCUSSION

Streamflow Study

The flow study conducted in 1976 provided data to evaluate various possible release schedules (Haines, 1981b). Calculations of usable area for trout production using an unweighted criteria method showed optimum flow to be 0.8 to 1.1 m^3/s for Study Area 1 and 2.0 to 2.3 m^3/s for Study Area 2 (Tables 1 and 2).

A weighted criteria method of analyzing the data gave different optimum flows for each of several trout habitat parameters. Subjective cover (any place an adult trout might hide) and food-producing habitat generally increased with flow up to the highest flows measured. Optimum flows for resting habitat were 0.28 to 0.56 m^3/s for Study Area 1 and 1.4 to 1.7 m^3/s for Study Area 2. Spawning habitat was greatest in Study Area 1 at flows of 2.1 to 2.5 m^3/s, but continued to increase with flow up to at least 3.1 m^3/s at Study Area 2.

These data suggested that the project-increased flows in Indian Creek below Antelope Dam (from about 0.085 m^3/s) substantially increased trout habitat. Based on the unweighted criteria method, usable trout habitat in upper Indian Creek (Study Area 1) increased 440 percent from 43 to 233 m^2. Specific habitat parameters, evaluated by the weighted criteria method, also increased substantially. Subjective cover increased 280 percent, from 10 to 38 m^2. Food-producing area increased 525 percent, from 8 to 50 m^2. Resting habitat increased 70 percent, from 208 to 356 m^2, and spawning habitat increased 575 percent, from 0.4 to 2.7 m^2 (Table 1).

Increasing the summer, fall, and winter release (July to March) from 0.28 to 0.56 m^3/s during 1978 and 1980 further increased trout habitat, as measured by these parameters [1/]. Specifically, usable area increased 65 percent, from 233 to 382 m^2; subjective cover, 120 percent, from 38 to 84 m^2; food-producing area, 138 percent, from 50 to 119 m^2; resting habitat declined 5 percent, from 356 to 340 m^2; and spawning area increased nearly 800 percent, from 2.7 to 24 m^2.

1/ Streamflow was reduced to 0.28 m^3/s in 1979 due to very low runoff conditions.

TABLE 1

TROUT HABITAT IN UPPER INDIAN CREEK
(STUDY AREA 1) AT VARIOUS STREAMFLOWS 1/

Streamflow (m^3/s)	0.085	0.14	0.28	0.56	0.85
Unweighted Criteria Method					
Usable Area (m^2)	43	97	233	382	497
Weighted Criteria Method					
Subjective Cover (m^2)	10	18	38	84	132
Food-Producing Area (m^2)	8	20	50	119	191
Resting Habitat (m^2)	208	250	356	340	260
Spawning Habitat (m^2)	0.4	1.1	2.7	24	50

TABLE 2

TROUT HABITAT IN INDIAN CREEK NEAR FLOURNOY BRIDGE
(STUDY AREA 2) AT VARIOUS STREAMFLOWS 1/

Antelope Reservoir Release (m^3/s)	0.085	0.14	0.28	0.56	0.85
Streamflow at Area 2 (m^3/s)	0.65	0.71	0.85	1.13	1.42
Unweighted Criteria Method					
Usable Area (m^2)	519	570	698	953	1190
Weighted Criteria Method					
Subjective Cover (m^2)	69	72	78	91	104
Food-Producing Area (m^2)	126	136	159	207	255
Resting Habitat (m^2)	938	947	970	1014	1043
Spawning Habitat (m^2)	150	160	184	233	280

1/ Adapted from DWR Technical Information Report 81-2.

Trout habitat in Indian Creek near Flournoy Bridge, represented by Study Area 2, also increased, but much more modestly, due to considerable tributary inflow which reduces the impact of flow increases from Antelope Reservoir (Table 2).

Usable trout habitat in Study Area 2 increased 34 percent, from 519 to 698 m^2; subjective cover increased 13 percent, from 69 to 78 m^2; food-producing area increased 26 percent, from 126 to 159 m^2; resting habitat increased 3 percent, from 938 to 970 m^2; and spawning habitat increased 23 percent, from 150 to 184 m^2.

Operation studies were prepared to demonstrate the impact of various flow releases on water levels at Antelope Reservoir. Because average annual inflow is about 1.7 times storage capacity, the reservoir spills 50 to 200 days most years. Thus, summer flows in Indian Creek could be increased with a relatively small increase in the drawdown of Antelope Reservoir. The original schedule called for releases of 0.56 m^3/s from April through June and 0.28 m^3/s the rest of the year. To minimize drawdown during the recreation season, these were to be reduced in dry years when the reservoir is not full on May 1.

This release schedule results in an average September 1 drawdown of about 0.66 m and an average maximum annual drawdown of 1.09 m, which usually occurs in late October or November (Table 3). The revised release schedule (0.56 m^3/s year-long) results in an average September 1 drawdown of 0.96 m and an average maximum drawdown of 1.96 m, which usually occurs in late October through December. The average mid-summer reduction in surface area of Antelope Reservoir with a release of 0.56 m^3/s would be only 1.2 ha more than with the original release schedule. This is because the revised schedule calls for a reduced release during the spring months of exceptionally dry years. With a year-long release of 0.85 m^3/s, the average September 1 drawdown would increase to 1.45 m, with an average maximum drawdown of 3.22 m, which would usually occur sometime between late November and the end of January (Table 3 and Appendix C).

The operation studies showed that flow releases up to at least 0.85 m^3/s provide more water surface in Indian Creek than is lost in Antelope Reservoir due to increased drawdown. Since stream habitat is considerably more productive per unit area than reservoir habitat, this tradeoff is reasonable up to at least 0.85 m^3/s (Table 4).

TABLE 3

ANTELOPE RESERVOIR DRAWDOWN 1/

	Average Drawdown in Metres	
	September 1	Annual Maximum
Original Release Schedule (0.56 m^3/s April 1-June 30; 0.28 m^3/s July 1-March 31)	0.66	1.09
Revised Release Schedule (0.56 m^3/s year-round)	0.96	1.96
Alternative Release Schedule (0.85 m^3/s year-round)	1.45	3.22

TABLE 4

ESTIMATED CHANGE IN AVERAGE MID-SUMMER SURFACE AREA OF ANTELOPE RESERVOIR AND INDIAN CREEK WITH VARIOUS DOWNSTREAM RELEASES 1/

	Change in Mid-Summer Water Surface Area (hectares)	
Downstream Release (m^3/s)	Antelope Reservoir	Indian Creek--- Dam to Taylorsville
0	- 0.8	0
0.08 (Pre-project)	- 1.6	+ 6.9
0.28 (Original)	- 8.9	+13.4
0.56 (Revised)	-10.1	+19.8
0.85 (Alternative)	-17.8	+25.5

1/ Based on operation studies for water years 1962-1980

Fish Population Surveys

Six stream sections totaling about 280 m (1.5 percent) of upper Indian Creek were sampled each year. Eight species of fish were caught during four years of sampling (Table 5). Rainbow trout, brown trout, and Sacramento squawfish were the only species caught all four years. Sacramento squawfish and Sacramento sucker were caught only at the lowest station, just above Flournoy Bridge.

TABLE 5

SPECIES CAUGHT IN FISH POPULATION SAMPLING, INDIAN CREEK

Species	1977	1978	1979	1980
Brown trout (*Salmo trutta*)	X	X	X	X
Rainbow trout (*Salmo gairdneri*)	X	X	X	X
Golden shiner (*Notemigonus crysoleucas*)		X	X	X
Sacramento squawfish (*Ptychocheilus grandis*)	X	X	X	X
Speckled dace (*Rhinichthys osculus*)	X			
Lahontan redside (*Richardsonius egregius*)		X		X
Sacramento sucker (*Catostomus occidentalis*)	X	X		X
Brown bullhead (*Ictalurus nebulosus*)		X		X

The trout in Indian Creek survived the low flow conditions of 1976-77 surprisingly well, perhaps in part because fishing pressure was also very low. When fish populations were sampled in October 1977, trout were concentrated in pools and seemed to be in good condition, except for the lowest station just above Flournoy Bridge, where skin parasites were common.

Photo, opposite--DFG personnel take samples by electrofishing. An electrical charge stuns fish, permitting them to be gathered, identified, measured, and weighed. They are then released.

Generally, trout population levels in 1977 and 1978 were similar to those sampled some years earlier (1968-70) (Table 6).

TABLE 6

INDIAN CREEK TROUT POPULATION TRENDS, 1962-1980
(Number of trout per 100 m of stream sampled)

Years	Number of Samples	Total Number of Trout	Number of Adult Trout
1962-64 1/ (Pre-project)	7	12	4
1968-70 1/ (Post-project)	7	59	20
1977 2/	6	80	32
1978 2/	6	59	21
1979 2/	6	277	23
1980 2/	6	156	101

1/ Gerstung (1973) and unpublished data

2/ DFG Contract Services Section Information Reports 78-1, 79-2, 80-1, and 81-1

However, the relatively low numbers of juvenile rainbow trout in 1977 and juvenile brown trout in 1978 suggest that spawning and incubation conditions and the subsequent survival of young trout were poor during 1977 (Table 7). The release from Antelope Reservoir was increased to 0.56 m^3/s in March 1978. This improved habitat conditions for rainbow trout that spring, resulting in an increased number of young rainbow trout in the 1978 population. Brown trout also reproduced very well that fall, producing a large increase in young brown trout in the 1979 population.

By 1980, these juvenile trout had become adults ($\geq$ 127 mm), and they began to enter the fishery that August. The number of juvenile brown trout collected in September 1980 declined from 1979 levels probably because the release from Antelope Reservoir was reduced to 0.28 m^3/s in 1979 due to poor runoff conditions and this reduced spawning habitat. Antelope Reservoir spilled in spring 1980 and a relatively large number of juvenile rainbow trout were captured that fall. They may have come from the reservoir or

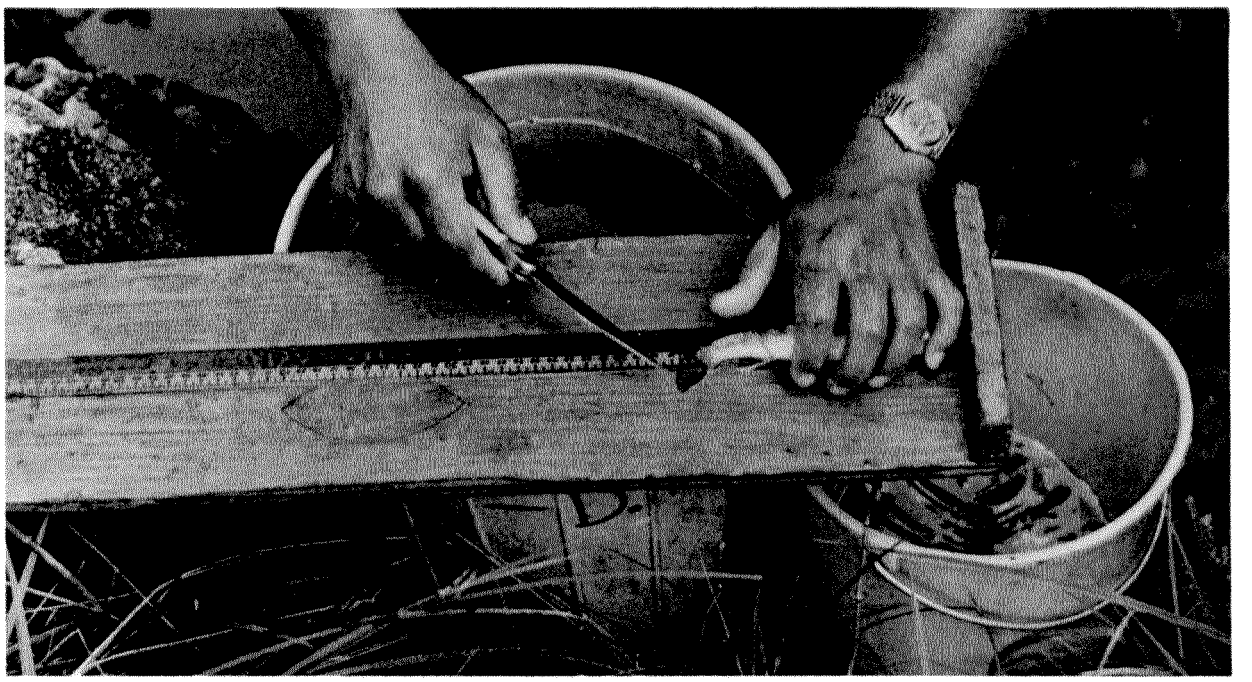
TABLE 7

TROUT POPULATIONS AND BIOMASS IN
SELECTED SECTIONS OF INDIAN CREEK
1977-80 1/

	Brown Trout			
	1977	1978	1979	1980
Population estimate	200	142	713	325
Biomass (gm/m^2)	4.7	2.7	3.6	5.7
Adult trout ($\geq$ 127 mm)	77	52	46	250
Juvenile trout (< 127 mm)	123	90	667	75

	Rainbow Trout			
	1977	1978	1979	1980
Population estimate	10	28	32	139
Biomass (gm/m^2)	0.5	0.4	0.7	1.7
Adult trout ($\geq$ 127 mm)	7	9	15	50
Juvenile trout (< 127 mm)	3	19	17	89

1/ DFG Contract Services Section Information Reports 78-1, 79-2, 80-1, and 81-1--based on population sampling in six locations totaling about 280 m (1.5 percent) of upper Indian Creek



were spawned in the creek. Apparently most of the rainbow trout that leave Antelope Reservoir when it spills are caught by anglers or migrate downstream. Relatively few are collected in the fall population samples.

Age and growth data did not indicate statistically significant changes in growth rates for brown trout during the study period. Not enough usable scales from rainbow trout were collected to calculate growth rates for any year.

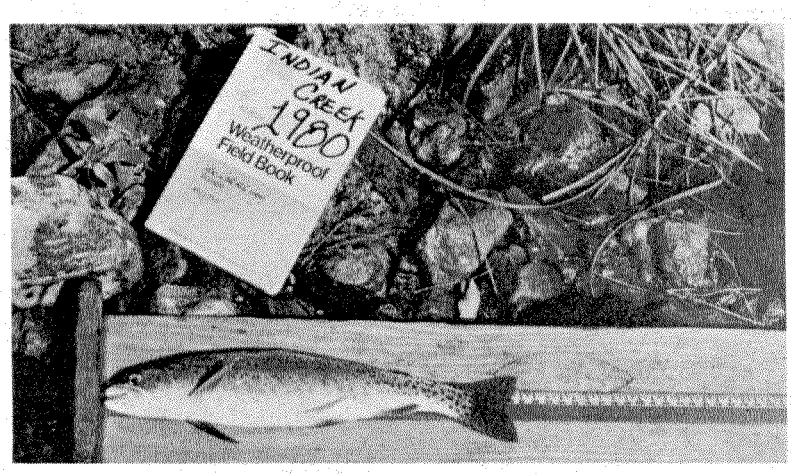
The coefficient of condition is a measure of the relative well-being or plumpness of fish. This coefficient declined for brown and rainbow trout each year of the study, about 15 percent overall (Table 8). A decline in condition factor sometimes occurs in fast-growing fish or may be due to larger average size. The significance of this trend in Indian Creek trout is unknown.

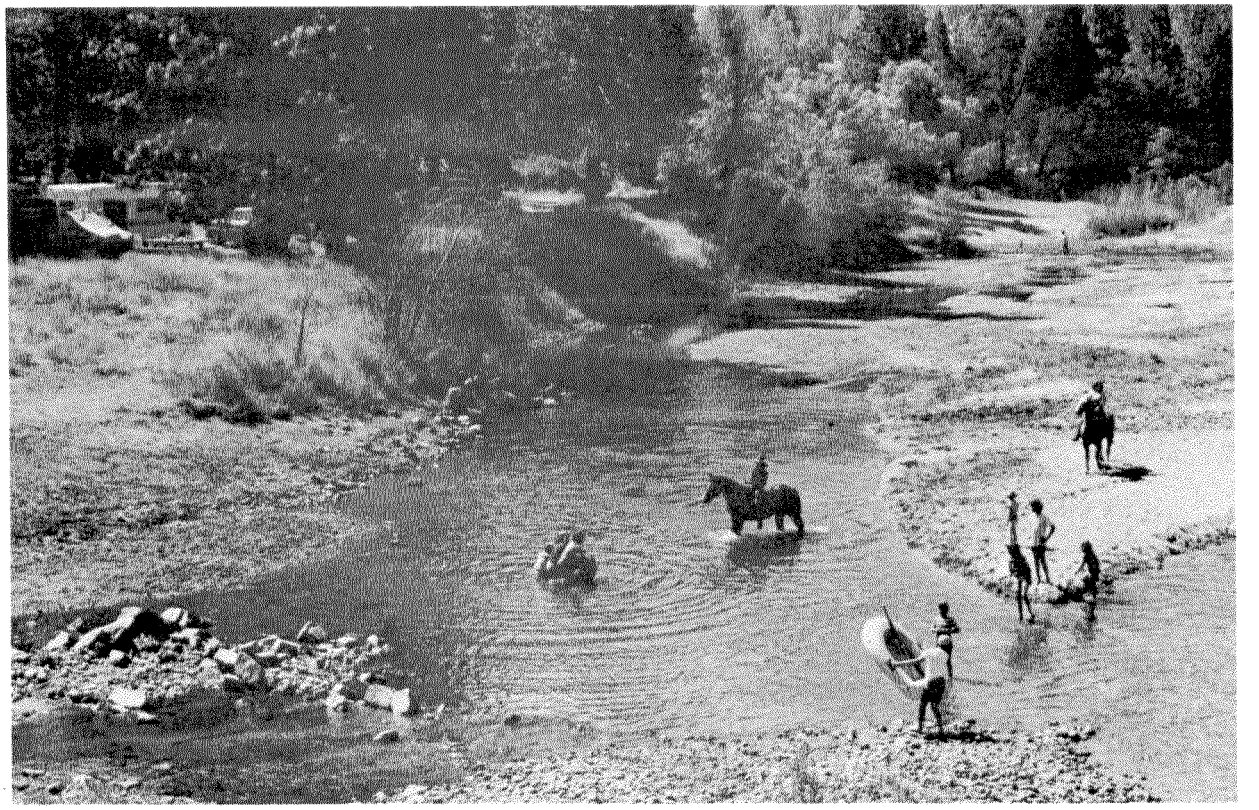
TABLE 8

COEFFICIENT OF CONDITION OF BROWN TROUT AND RAINBOW TROUT IN INDIAN CREEK 1/

Year	Brown Trout	Rainbow Trout
1977	1.201 ($\pm$ 0.339)	1.240 ($\pm$ 0.507)
1978	1.172 ($\pm$ 0.263)	1.188 ($\pm$ 0.478)
1979	1.076 ($\pm$ 0.344)	1.094 ($\pm$ 0.353)
1980	1.053 ($\pm$ 0.014)	1.078 ($\pm$ 0.039)

1/ Based on the formula $K = \text{weight}/\text{length}^3$, DFG Contract Services Section Information Reports 78-1, 79-2, 80-1, and 81-1





County park near Taylorsville, Indian Creek

Recreation Surveys

Indian Creek

Major recreation activities on Indian Creek included fishing, camping, swimming and beach use, relaxing, picnicking, and sightseeing. Recreation use totaled 63,000 hours in 1978, 62,000 hours in 1979, and increased to 75,000 hours in 1980. Estimated hours of fishing, swimming and beach use, and miscellaneous activities were less in 1979 than in 1978 or 1980 (Table 9 and Figure 2). Camping and picnicking increased each year of the study. Relaxing was the only activity that was lower in 1980 than in the two previous years. This may have been due to a change in activity interpretation by the surveyors. Expressed in recreation days, Indian Creek use totaled 40,000 in 1978, 49,000 in 1979, and 42,000 in 1980. The increase in 1979 was due to a shorter length of stay that year.

Average length of stay for day use visitors was 2.8 hours in 1978, 2.5 hours in 1979, and 2.9 hours in 1980. Harmonic mean length of stay was 1.6, 1.3, and 1.8 hours. (The "harmonic mean" is derived from a formula that

corrects a statistical bias that would otherwise be built in to surveys of this type.) Overnight use followed a similar pattern with a high of 4.6 days in 1978, 3.9 days in 1979, and 4.0 days in 1980.

TABLE 9

COMPARISON OF ESTIMATED RECREATION
USE ON INDIAN CREEK, 1978-80 1/

Activity	Hours of Recreation		
	1978	1979	1980
Fishing (includes crayfishing)	12,050	7,500	12,400
Camping	15,950	16,600	19,900
Swimming and beach use	9,600	8,500	11,600
Relaxing	13,700	17,000	9,500
Picnicking	2,050	2,800	6,900
Sightseeing	2,000	1,400	3,900
Miscellaneous	7,650	8,200	10,800
Total Hours	63,000	62,000	75,000
Recreation Days	40,000	49,000	42,000

1/ DWR Technical Information Reports
79-1, 80-1, and 81-1

In 1979, Indian Creek recreation was affected by a temporary gasoline shortage and lower streamflows. Gasoline supplies in metropolitan areas were uncertain in early 1979, and many service stations had long lines and short business hours. This uncertainty slowed recreation use at Indian Creek and Antelope Lake through May. However, on Memorial Day weekend both the creek and reservoir had capacity use, and recreation use remained high thereafter.

A higher percentage of visitors came from the northeast counties in 1979 and 1980. Relatively fewer people visited Antelope Reservoir and Indian Creek from the San Francisco Bay area and Southern California, and relatively more came from the local area. People seemed to be making shorter trips and staying longer.

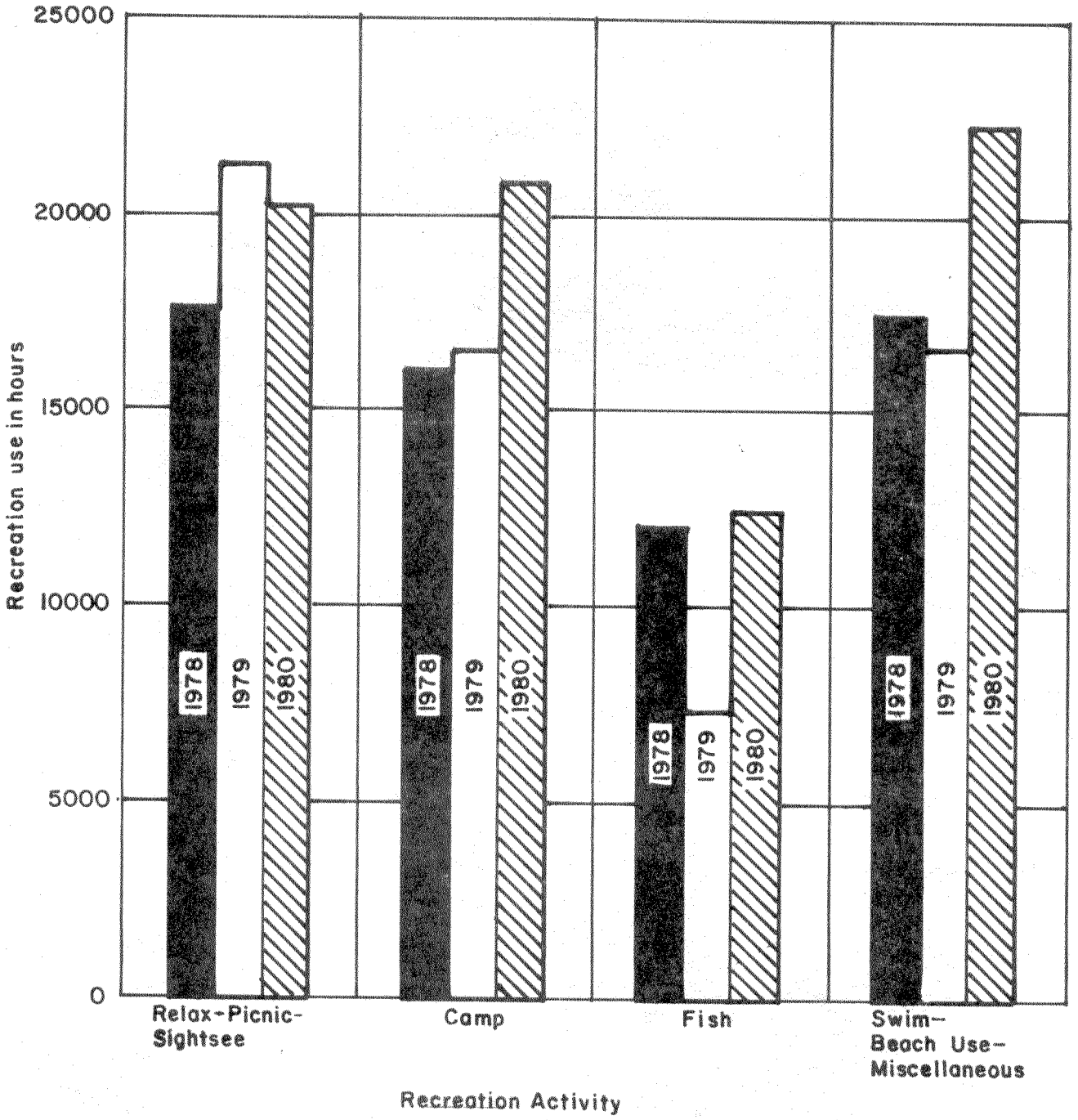


Figure 2 Estimated Recreation Use at Indian Creek, by Activity, 1978-80

Antelope Reservoir

The USFS reported that all types of recreation use on Antelope Reservoir totaled 83,200 recreation days in 1978, 273,500 in 1979, and 223,000 in 1980 (Appendix G).

When the reservoir was built, recreation use resulting from the reservoir, its recreation facilities, and downstream flow enhancement was expected to far exceed use of the area without the project (DWR, 1962). In 1980, recreation use at the project and downstream exceeded even the predicted use by about 2½ times (Table 10).

TABLE 10

COMPARISON OF PREDICTED AND ACTUAL RECREATION USE OF ANTELOPE RESERVOIR AND UPPER INDIAN CREEK, 1980

	Recreation Use, in Recreation Days		
	Antelope Reservoir	Upper Indian Creek	Totals
Predicted use 1/	76,000	24,000	100,000
Actual use 2/	223,000	31,000	254,000

1/ DWR Bulletin 117-8, page 32

2/ Antelope Reservoir use reported by USFS; Indian Creek use between Antelope Dam and Taylorsville from DWR Technical Information Report 81-1, page 7

Comparison of the reported monthly recreation use for 1978-80 with the water surface elevation of Antelope Reservoir illustrates two important points. First, reservoir levels each month of the recreation season (May through September) were very similar, considering the differences in runoff and downstream releases in these years (Table 11). This suggests the dry year criteria (used in 1979) minimize drawdown as intended. Second, recreation use levels apparently were not related to reservoir levels. They were probably determined by other factors, such as weather, available leisure time, fishing quality, gasoline availability, etc.

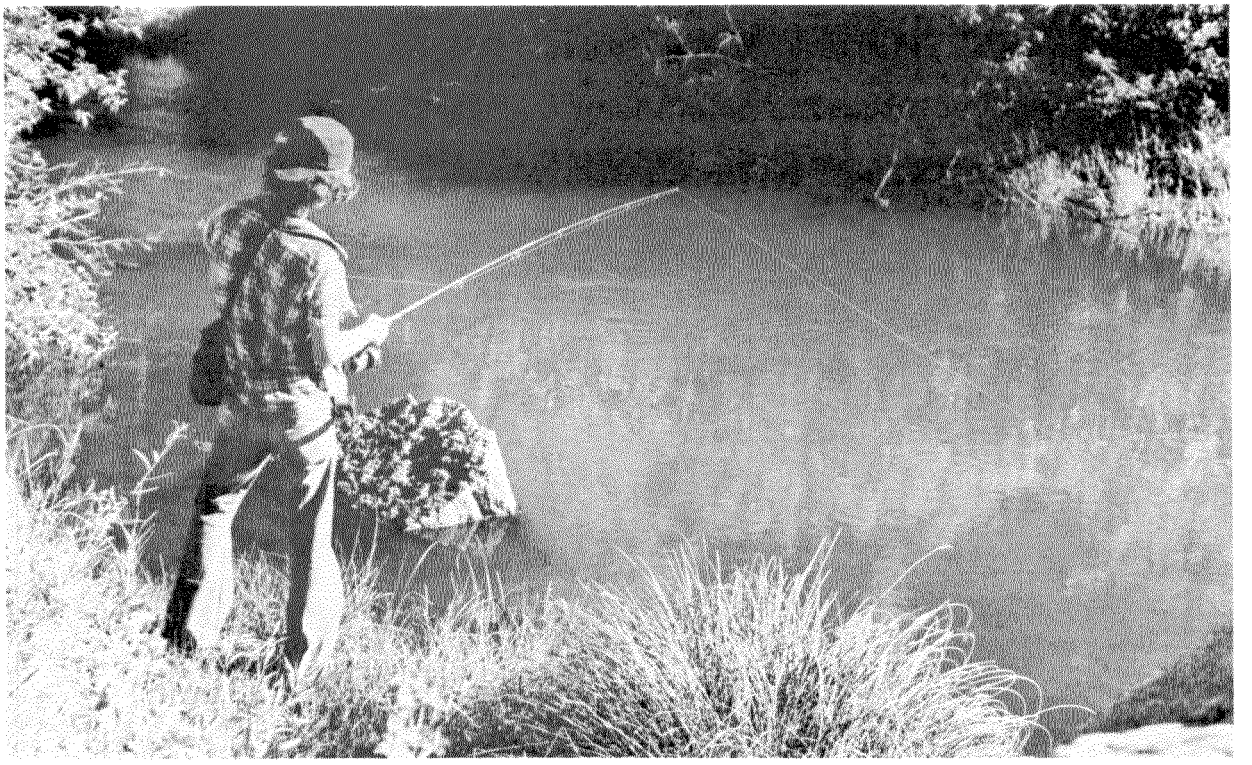
TABLE 11

REPORTED RECREATION USE AT ANTELOPE RESERVOIR
VS. WATER SURFACE ELEVATION, 1978-80

Year	1978	1979	1980
May	20,300 1/ (1 524.91) 2/	29,200 (1 524.49)	35,300 (1 524.91)
June	12,400 (1 524.70)	57,600 (1 524.55)	35,900 (1 524.79)
July	7,500 (1 524.46)	42,600 (1 524.24)	45,500 (1 524.52)
August	5,000 (1 523.91)	51,400 (1 523.85)	43,800 (1 524.03)
September	5,500 (1 523.45)	41,700 (1 523.54)	23,300 (1 523.57)
Downstream Release	0.56 m^3/s	0.28 m^3/s	0.56 m^3/s

1/ Monthly recreation days reported by USFS.

2/ Mid-month water surface elevation of Antelope Reservoir. Spillway elevation is 1 524.61 metres.



Creel Census

Indian Creek

Angler use on Indian Creek was higher in 1978 and 1980 when the flow release was 0.56 m^3/s than in 1979 when the release was 0.28 m^3/s. Estimated angler use totaled 11,250 hours in 1978, 7,250 in 1979, and 12,300 in 1980, excluding crayfishing in lower Indian Creek. The total number of trout caught (brown and rainbow) showed a similar pattern to angler use; more trout of both species were caught in 1978 and 1980 than in 1979. Fishing success (trout caught per hour) for brown trout also followed the same pattern, but the catch rate for rainbow trout increased each year of the study (Table 12). The catch of other species (primarily brown bullhead, squawfish, bluegill, and golden shiner) was small all three years.

The mean length of brown trout caught by anglers increased slightly each year, from 23 cm in 1978 to 24.5 cm in 1980. However, the length of rainbow trout declined from 26.5 cm in 1978 to 23 cm in 1980, largely reflecting the size of fish entering the creek from Antelope Reservoir (Table 13).

TABLE 12

ESTIMATED ANGLER USE AND SUCCESS,
INDIAN CREEK, 1978-80 1/

	1978	1979	1980
Estimated angler hours	11,250	7,250	12,300
Brown trout caught	3,830	1,375	3,050
Brown trout caught/hour	0.34	0.19	0.25
Rainbow trout caught	2,130	1,575	3,580
Rainbow trout caught/hour	0.19	0.22	0.29
Other fish caught	180	50	390
Other fish caught/hour	0.02	0.01	0.03

1/ DWR Technical Information
Reports 79-1, 80-1, and 81-1

TABLE 13

MEAN LENGTH OF BROWN TROUT AND RAINBOW
TROUT CAUGHT IN INDIAN CREEK, 1978-80 1/

	Mean Length in Centimetres		
	1978	1979	1980
Brown trout	23.0	24.0	24.5
Rainbow trout	26.5	23.0	23.0

1/ DWR Technical Information
Reports 79-1, 80-1, and 81-1

Most of the fish caught each year were taken from upper Indian Creek (above Flournoy Bridge) where flow releases from Antelope Reservoir have the most impact. In 1978, 82 percent of the fish were caught in upper Indian Creek; comparable figures for 1979 and 1980 were 60 percent and 87 percent.

Angling use of Indian Creek is relatively light compared to streams included in DFG's Wild Trout Program. On a per-kilometre basis, fishing use at Indian Creek was one-eighth to one-half of the levels reported for these streams (Snider, 1980 and 1981). Indian Creek fishing use is perhaps more

typical of roadside catchable trout streams in the area, such as Deer Creek along Highway 32 in Tehama County. However, the catch of trout per hour and the average size of the brown trout caught from Indian Creek compare favorably with all of these streams (Table 14).

TABLE 14

COMPARISON OF ANGLER USE AND CATCH RATE OF TROUT FOR SELECTED SIERRA STREAMS 1/

Stream	Year	Stream Length (km)	Angler Hours Per km	All Trout Catch Per Hour	Average Size (cm)
Lower Hat Creek	1973	5.6	3,200	0.45	NA
East Walker River	1975-76	14	1,000	0.21	NA
South Fork Kings River	1976-78	18	1,200	0.51	22
Deer Creek	1980	18	400	0.71 2/	NA
Upper Indian Creek	1978	18	400	0.70	23
Upper Indian Creek	1979	18	200	0.51	24
Upper Indian Creek	1980	18	500	0.66	24

1/ Snider, 1980 and 1981, and DWR Technical Information Reports 79-1, 80-1, and 81-1

2/ 90 percent planted catchable trout

Although no studies were conducted specifically to evaluate angler opinions on streamflow and fishing success, discussions with anglers during the creel census suggested that they generally felt that higher flows meant better fishing. Many thought the creek looked too small or too low for good fishing at 0.28 m^3/s. Some commented that fishing seemed better at flows much higher than 0.56 m^3/s. These subjective opinions were supported by angling success data collected at different flows.

Antelope Reservoir spills most years, often for extended periods. When the lake elevation is more than about 0.15 m above the spillway lip (corresponding to a spill of about 1.4 m^3/s), many fish swim out of the lake and wash into Indian Creek. This occurred in 1978 and 1980, and rainbow trout and brown bullhead from Antelope Reservoir contributed to the Indian Creek

fishery both years. Anglers are attracted to upper Indian Creek any time the reservoir is spilling. They know from past experience and reports of other anglers that fishing is usually good just below the dam when the reservoir is spilling.

However, angler use on Indian Creek was higher in 1978 and 1980 throughout the season, long after the reservoir spill ended. Overall fishing success was higher both seasons with the 0.56 m^3/s release than during 1979 when the release was 0.28 m^3/s (Table 15). Also, fishing success for brown trout was higher in 1978 and 1980 than in 1979, and brown trout in Indian Creek do not come from the lake. Only the rainbow trout populations are augmented when the reservoir spills.

TABLE 15

RELATIONSHIP OF STREAMFLOW AND ANGLING SUCCESS FOR BROWN AND RAINBOW TROUT, UPPER INDIAN CREEK, 1978-80

Streamflow (m^3/s)	Rainbow Trout Catch/Hour	Brown Trout Catch/Hour	Combined Catch/Hour
0.21-0.42	0.13	0.27	0.40
0.43-0.70	0.11	0.30	0.41
0.71-1.13	0.24	0.31	0.55
1.14-1.70	0.26	0.70	0.96
1.70-2.26	0.45	0.63	1.08
2.27-3.26	0.25	0.21	0.46
3.27-4.81	0.42	0.29	0.71
4.82-6.80	0.43	0.30	0.73
Means	0.22	0.30	0.52

Angling success in upper Indian Creek generally increased with streamflow up to about 2.3 m^3/s. Since large numbers of rainbow trout enter the creek when the reservoir spills, the higher catch rate for this species may simply be related to the additional fish provided by spills. The catch rate for rainbow trout was highest for flows ranging from 1.7 to 6.8 m^3/s, flows that occur only when the reservoir spills. However, brown trout are resident in Indian Creek and are not found in the reservoir. Additional fish provided by reservoir spill could not explain why the catch rate for brown trout was highest for flows ranging from 1.1 to 2.3 m^3/s (Table 15 and Figure 3).

Thus, it seems likely that higher flows do provide better fishing conditions. The additional rainbow trout associated with reservoir spills no doubt are a factor, but better trout cover and greater turbulence associated with higher flows also may be important.

In summary, periods of reservoir spill in 1978 and 1980 and higher flows attracted more anglers to the creek, while the gasoline shortage and lower flows reduced fishing in 1979. However, the fact that increased fishing continued all season in 1978 and 1980, long after the reservoir spills ended, suggests that higher streamflows played an important part in the higher use those years.

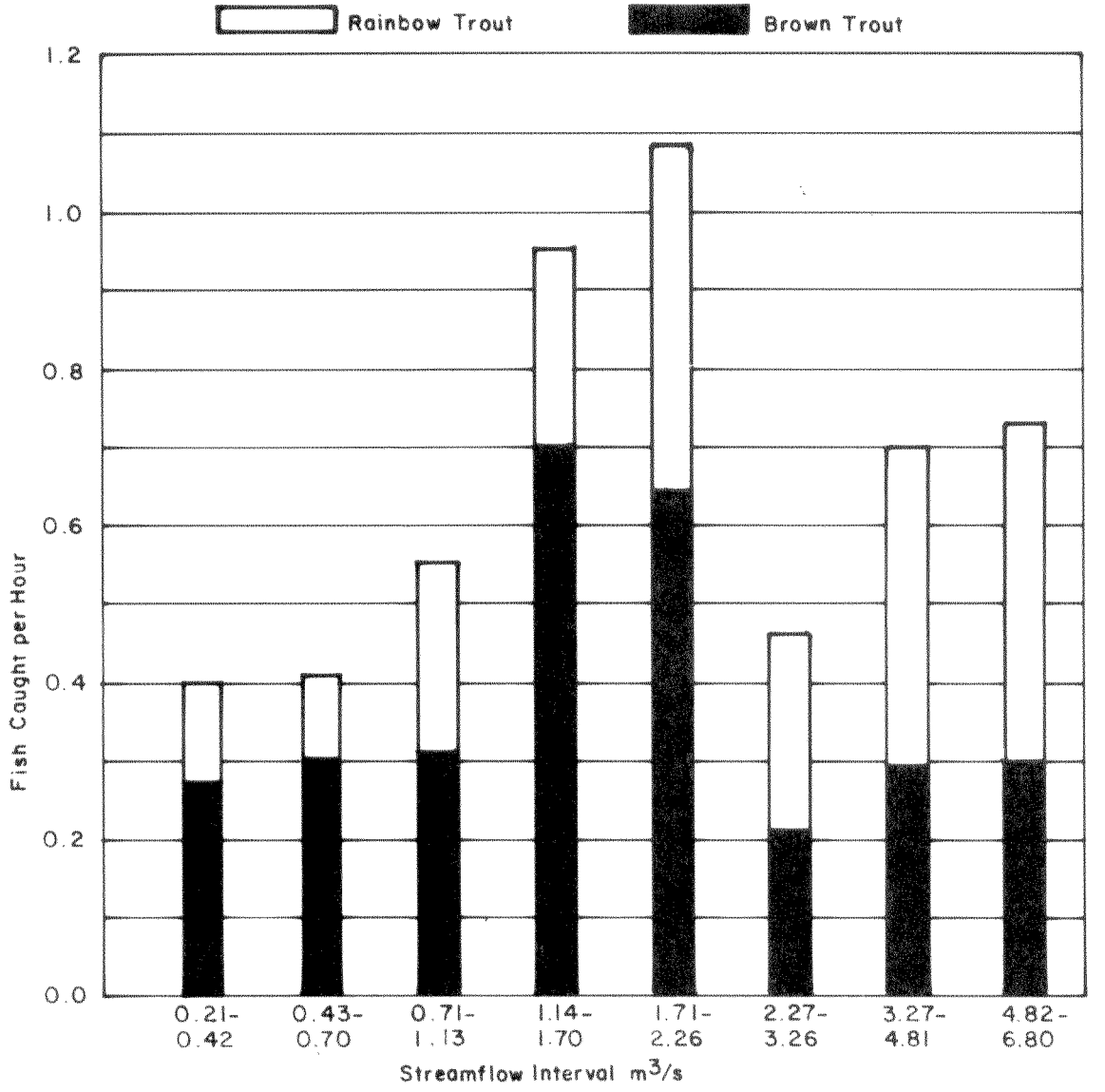


Figure 3 Angling Success Versus Streamflow in Upper Indian Creek, 1978-80

The sport catch and trout population estimates can be combined to illustrate the changes that have occurred in the Indian Creek fishery during the study period (Table 16). To make it easy to visualize the relative numbers of fish in the stream and the magnitude of the population changes, these estimates are expressed as numbers and weight of trout per 100 m of stream. For example, the data suggest that 1977 trout populations might have been similar to 1978 if there had been a similar amount of fishing. There are large increases in populations of brown trout in 1979 and rainbow trout in 1980 and an equally large increase in adult (catchable-sized) trout of both species in 1980. From an angler's perspective, the number of adult trout in a stream largely determines potential success.

TABLE 16

SPORT CATCH AND FALL TROUT POPULATIONS
IN UPPER INDIAN CREEK, 1977-80
(expressed as numbers of trout and
weight in grams per 100 m of stream)

	Sport Catch 1/		Fall Trout Population 2/		
	Number of Trout Caught	Total Weight	Number of Trout	Total Weight	Adult Trout
Brown Trout					
1977	Unknown 3/		76	2 560	29
1978	20	2 700	49	2 470	18
1979	8	1 150	265	3 130	17
1980	17	2 500	109	5 230	84
Rainbow Trout					
1977	Unknown 3/		4	280	3
1978	8	1 430	10	350	3
1979	2	340	12	640	6
1980	16	2 080	47	1 600	17

1/ Based on estimated catch of trout in 18 km of upper Indian Creek below Antelope Dam.

2/ Based on fish population sampling in six locations totaling about 280 m (1.5 percent) of upper Indian Creek.

3/ No creel census was conducted in 1977, but little or no fishing occurred because the road along upper Indian Creek was closed for reconstruction. This probably left a relatively large population of adult brown trout in fall 1977.

Antelope Reservoir

Antelope Reservoir fishing was censused in 1978, 1979, and 1980 along with the creel census on Indian Creek. Catch per hour of rainbow trout by boat fishermen increased from 0.18 in 1978 to 0.32 in 1980. Catch per hour by boat fishermen also increased, from 0.33 in 1978 to 0.61 in 1980. During the same period, the average length of rainbow trout decreased from 29 cm to 23 cm due to changes in the size of fish stocked and possible competition with brown bullhead and golden shiner. Brown bullhead reappeared in the fishery in August 1978 and the catch per hour and average length for this species increased each year of the study (Table 17).

TABLE 17

ANTELOPE LAKE CREEL CENSUS 1/

	1978	1979	1980
Angler Hours Censused			
Shore	2,076	5,510	2,005
Boat	248	321	277
Rainbow Trout			
Shore--Catch/Hour	0.18	0.28	0.32
Boat--Catch/Hour	0.33	0.55	0.61
Average Length of Rainbow Trout	29 cm	26 cm	23 cm
Brown Bullhead			
Shore--Catch/Hour	0.01	0.09	0.16
Boat--Catch/Hour	0	0.03	0.01
Average Length of Brown Bullhead	16.5	18.5	19.5

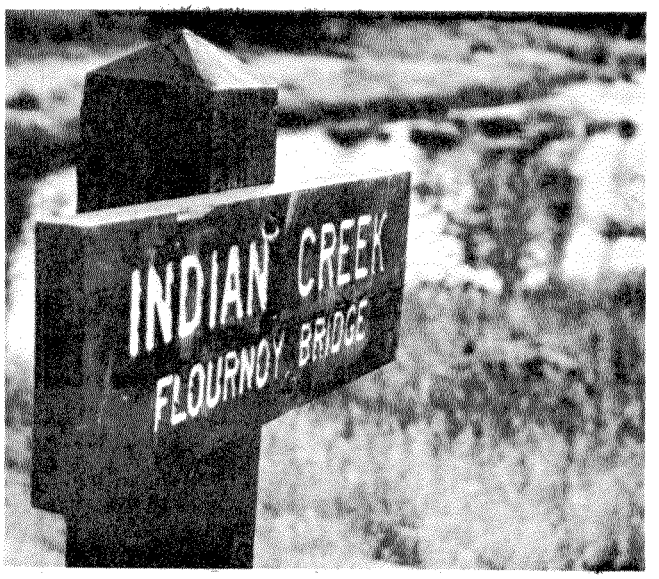
1/ Hinton, 1979; Haines, 1980b; and Hinton, 1981.

In 1979, total fishing use and catch for Antelope Reservoir were calculated (Haines, 1980). An estimated 70,000 hours (22,000 angler days) of shore fishing and 44,000 hours (13,000 angler days) of boat fishing were spent at Antelope Reservoir during the traditional trout season, April 28 to November 15. Shore anglers caught about 19,000 rainbow trout and boat fishermen about 20,000 trout. About 9,000 brown bullhead were caught. Brown bullhead are a major part of the reservoir fishery and are actively sought by many anglers.

Water Quality Samples

Turbidity, electrical conductivity, pH, and temperature were monitored for three years at five locations on Indian Creek. The highest pH recorded was 9.0 and the lowest was 6.5, with mean of 7.3 for 127 samples. Turbidity was seldom above 6 JTU, with 4.2 the mean for 125 samples. Temperature was within tolerance limits for salmonids. During spring and fall, when rainbow and brown trout spawn, temperatures were never above 15° C. Temperatures never exceeded 20° C. for samples taken at mid-day to measure E.C., pH, and turbidity, but higher temperatures were occasionally recorded below Flournoy Bridge in the late afternoon or evening in 1979.

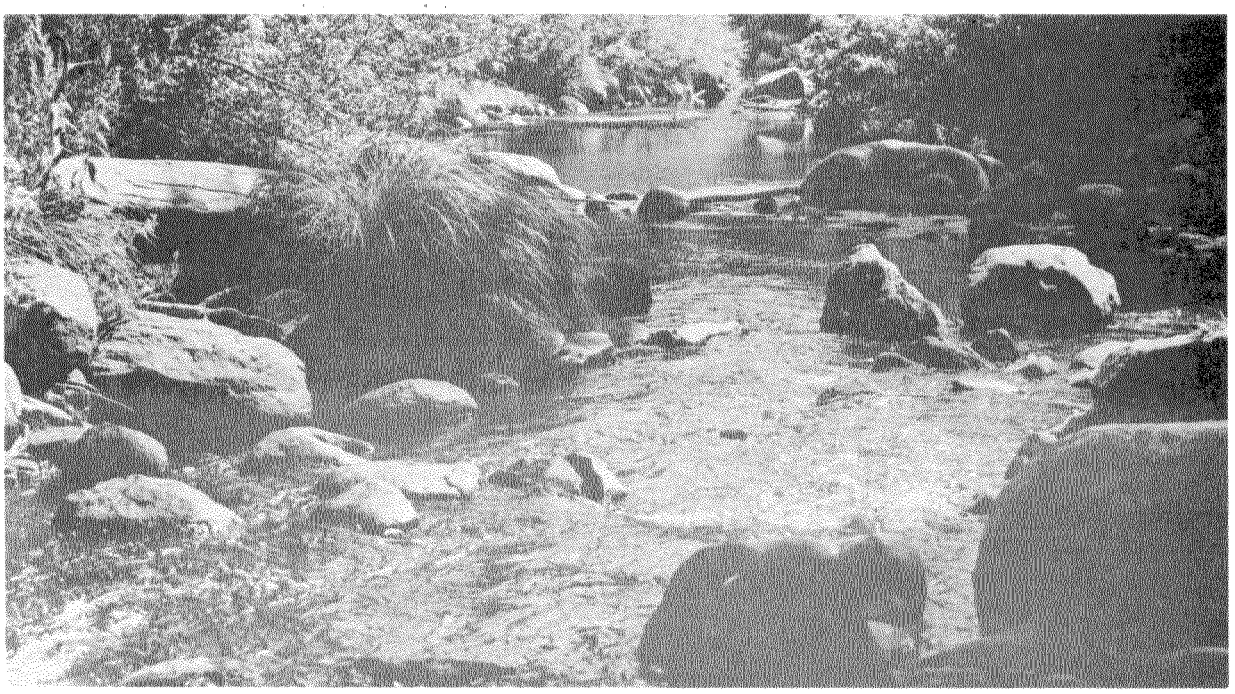
DWR made a water quality survey of Indian Creek in 1979 (Boles, 1980). It showed that the area immediately below Antelope Dam suffers from impacts commonly associated with releases from lower levels of productive reservoirs with high iron content. This area has a reduced aquatic insect fauna because of abnormal conditions. Temperatures are warmer than normal in winter and cooler than normal in the summer. This interferes with the life cycles of many insects. The food supply is limited to lake-dwelling plankton released from the dam and stream scavengers that feed on it. High nutrient concentrations in the hypolimnetic water cause abundant growth of rooted aquatic plants.



The unpleasant odor of hydrogen sulfide (H_2S) is apparent for about 3 km below Antelope Dam during the late summer months. This substance is formed from the anoxic bacterial reduction of sulfates in the hypolimnion of the reservoir. Fortunately, H_2S is rapidly displaced with exposure to oxygen in the stream so the odor dissipates a short distance downstream. The streambed in this reach has a reddish appearance caused by the precipitation of iron from the reservoir water when it is aerated in the stream.

Despite these late summer problems, the upper 3 km of Indian Creek supports good fish populations and a considerable amount of fishing in spring and early summer. Stream conditions rapidly improve downstream due to tributary inflow (Cold Stream enters 3 km below Antelope Dam) and the decreasing influence of the reservoir release. Generally, the 24-km reach from Cold Stream to Little Grizzly Creek is healthy and productive. There is a significant reduction in the number and total weight of aquatic insects in Indian Creek below Little Grizzly Creek. Lower Indian Creek apparently is affected by dissolved copper and other toxic waste materials from historic mining activities in upper portions of Little Grizzly Creek.

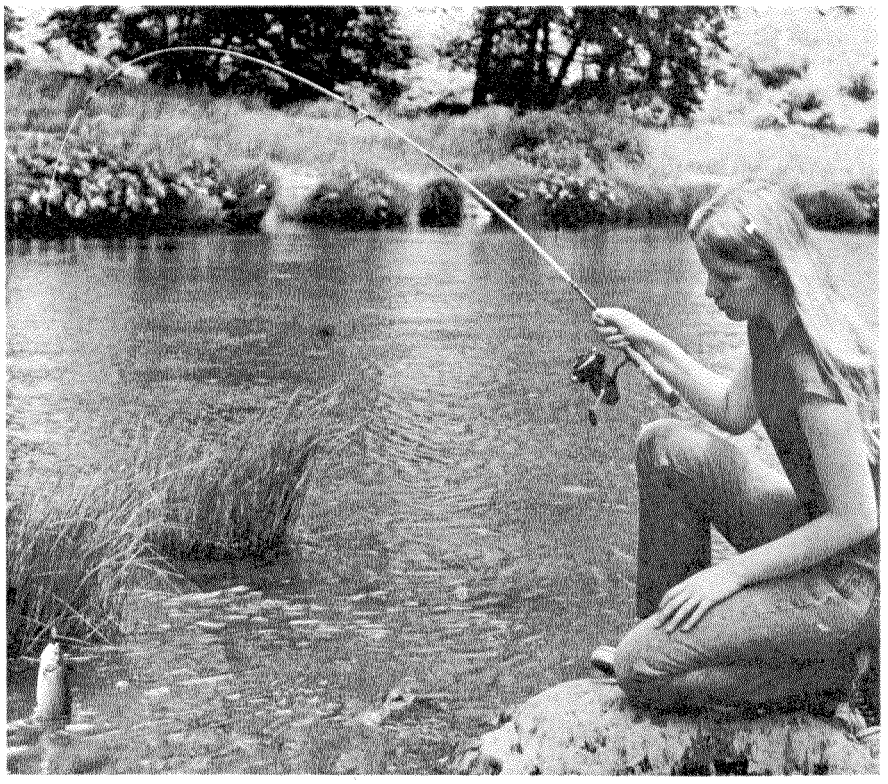
Antelope Reservoir was sampled in September 1979. A temperature and dissolved oxygen profile was obtained near the deepest part of the lake. Water samples were collected at the surface and every three metres to the bottom, and analyzed for pH, E.C., alkalinity, and turbidity. Surface and bottom samples were also collected for mineral, nutrient, and metal analyses. Water temperature ranged from 17° C. at the surface to 8° C. at the bottom, with a thermocline between 6 and 8 metres. Dissolved oxygen was 8 ppm at the surface, declined rapidly in the thermocline, and was zero below 11 metres. Field measured pH ranged from 8.7 at the surface to 6.3 at the bottom. E.C. ranged from 91 to 94. Alkalinity ranged from 43 to 46 ppm, suggesting a moderately rich reservoir. Turbidity was 1.0 FTU at the surface and 2.7 at the bottom.



PROPOSED REVISED OPERATION

Antelope Reservoir was planned using a very short record of Indian Creek runoff near the damsite and a much longer record of runoff at Indian Creek near Crescent Mills. Estimated runoff at the damsite was calculated from these data for the period 1920-55. The estimated average runoff was about 24 200 dam^3. Actual runoff for the 19 years of record at the damsite is much higher, about 46 600 dam^3. Both the estimated hydrology and the actual record of runoff indicate that about one year in five can be expected to be below 50 percent of normal. During these very low water years the release schedule should be modified early in the spring to avoid excessive drawdown of Antelope Reservoir the following summer.

At the start of this study, the USFS suggested that the proposed release schedule might better fit the runoff if the predicted April-to-July runoff was used to adjust the release, rather than waiting until May or June. The original release criteria required a specific release schedule for a one-year period based on May 1 storage at Antelope Reservoir. The proposed schedule changed the decision date to June 1 because Antelope Reservoir often is still filling in May. However, both schedules required continuing the previous year's schedule through the spring months, when a large portion of the year's runoff occurs and the water conditions for the following summer are determined. The February 1 forecast of water conditions in the drainage provides the



information needed to determine if an adjustment in the release schedule for the following year is required.

In general, if the April-to-July runoff is forecast to be more than 50 percent of normal (14 300 dam^3), release of 0.56 m^3/s through the spring helps reduce the reservoir spill and causes no major problems. DFG prefers a reservoir operation that minimizes reservoir spill and the accompanying loss of fish from the reservoir. Likewise, minimizing spill helps reduce possible downstream erosion. However, if the runoff is expected to be less than 50 percent of normal, release of 0.56 m^3/s through the spring months may keep the reservoir from filling by June 1, or result in a severe drawdown later during the summer and fall. In this case, it is prudent to reduce the release of 0.28 m^3/s in early February. This release should be maintained until the forecast substantially changes, or until the following winter, when the February 1 forecast of water conditions is made. The June 1 reservoir level should still be used to determine the release schedule for the following months, but the spring runoff forecast helps ensure that Antelope Reservoir fills, which should always be the primary objective.

Impacts of the Revised Operation

This report has discussed four levels of flow in Indian Creek:

1. The pre-project flow, about 0.085 m^3/s, which was the historic average low flow during late summer before the dam was built.

2. The original operation schedule, 0.56 m^3/s from April through June, and 0.28 m^3/s for the rest of the year, with appropriate reductions in dry years when Antelope Reservoir does not fill by May 1 (Appendix 2).

3. The revised operation schedule, 0.56 m^3/s year-round with reductions to 0.28 m^3/s or 0.14 m^3/s year-round in dry years when Antelope Reservoir does not fill by June 1 (Appendix 2).

4. A possible alternative schedule, 0.85 m^3/s year-round with reductions to 0.28 m^3/s or 0.14 m^3/s year-round in dry years when Antelope Reservoir does not fill by June 1. This flow schedule will not be recommended because of its adverse impacts on Antelope Reservoir recreation, but is evaluated for comparative purposes.

The revised operation would have a number of definable impacts. Potential benefits would include increased fish production and better stream fishing, increased streamside recreation use, increased energy production, slightly larger water supply to Oroville Reservoir, and reduced spill from Antelope Reservoir. Potential detriments would include minor decreases in the aesthetic quality of Antelope Reservoir, less ease of access to the lakeshore and use of recreation facilities (specifically the boat ramp) at Antelope Reservoir. There would be a slight reduction in water surface and fish production in the reservoir resulting from the increased drawdown. These potential impacts are discussed in the following sections.

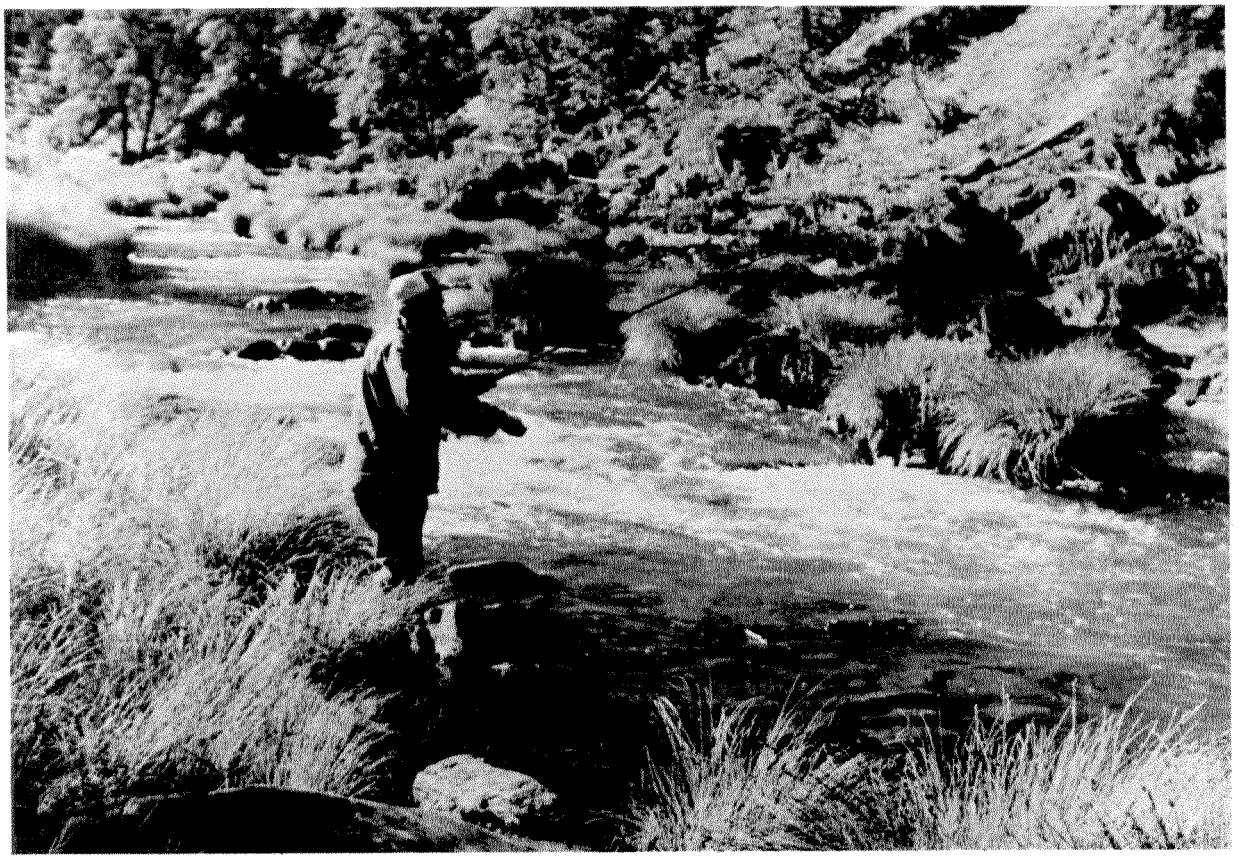
When evaluating the positive and negative impacts of the proposed revised operation, it is important to recognize that only the additional impacts of the proposed operation should be considered. The original operation provided considerable downstream enhancement over pre-project conditions and caused Antelope Reservoir to fluctuate 0.7 m or so by Labor Day each year. The proposed operation schedule would provide additional downstream enhancement and increase the September 1 reservoir drawdown to about 1 m. Only additional benefits and detriments caused by the proposed operation will be considered.

Potential Benefits

Fish Production

The higher flows released in 1978 improved spawning and rearing conditions and produced a large number of juvenile brown trout in 1979. These fish produced about a four-fold increase in adult brown trout in 1980. Rainbow trout populations also increased in 1978 and 1980, although spawning for this species is not much affected by the project releases, since they spawn during late spring when the reservoir is usually spilling.

The alternative release schedule (0.85 m^3/s) would provide even more trout habitat than the revised schedule. Presumably, this schedule might result in an even larger increase in trout production than the revised schedule.



Fishing Use and Quality

The increased numbers of catchable-sized trout in Indian Creek will support more fishing use, a higher catch per hour, or--more likely--some combination of the two. These changes should be noted as anglers discover the improved fishing. Apart from increased fish populations, higher flows seem to attract more anglers simply because the creek looks more fishable. The census data show that more trout are caught at higher flows, up to about 2.3 m^3/s. The proposed revised flow release will combine these factors to improve fishing and increase fishing use of upper Indian Creek.

Recreation Use

About half of the visitors to Indian Creek are anglers, but they also engage in other recreation activities, and they bring families and friends who often do not fish. An improved fishery will attract more anglers for day use and overnight camping; they will bring other recreationists with them, thus increasing general recreation on the creek.

Energy Production

The higher summer and fall flows provided by the revised operation would yield a small increase in hydroelectric energy production at Pacific Gas and Electric Company's (PG&E) North Fork Feather River system. Each dam^3 of water flowing through Rock Creek, Cresta, and Poe Power Plants produces about 1,300 kilowatt-hours of energy. If a small hydroelectric plant is ever built at Antelope Dam, the revised operation would increase energy production by about 60 percent, compared to the original schedule.

Water Supply

The revised operation would provide a minimal increase in water supply to Oroville Reservoir, to the extent that increased project releases reach and are released from Oroville Reservoir during years when it does not spill. Water rights agreements between DWR and PG&E require that water released from storage in Antelope Reservoir can be used only for streamflow enhancement in Indian Creek and the East Branch North Fork Feather River. Thus, the increased flows would not be available for other water users above Oroville Reservoir. The increase in flow is too small to measurably improve trout habitat between the PG&E power plants on the North Fork Feather River.

Reservoir Spill

The increased regulated release would cause a slightly greater drawdown of Antelope Reservoir each winter. In most years Antelope Reservoir would fill during the spring months and the increased drawdown would have little effect on reservoir spill. But in a few relatively dry years (50 to 75 percent of normal runoff) when Antelope Reservoir barely fills, the revised operation would reduce the amount and duration of spill. This situation would occur about one year in five or less.

DFG would prefer to minimize reservoir spill in order to reduce the loss of trout from the reservoir. The proposed operation schedule would provide only a minor reduction in the frequency and duration of spills. A higher release schedule would cause a larger drawdown each year, correspondingly less spill, and fewer rainbow trout leaving the reservoir.

Potential Detriments

Aesthetic Quality

The increased drawdown of Antelope Reservoir resulting from the revised operation would slightly diminish the beauty of the reservoir. It would reduce the average water surface elevation by 0.17 m during the recreation season (May through September) and the September 1 elevation by about 0.3 m. Of course, all lakes and reservoirs fluctuate. With no downstream release, Antelope Reservoir would still fluctuate slightly due to evaporation.

Observations during three years of study show that drawdown of a metre or so does not seriously harm the looks of the reservoir. Drawdown of more than about two metres causes a significant visual impact (an unvegetated ring around the reservoir shoreline), which is distracting. The alternative schedule would cause reservoir drawdown frequently exceeding two metres in late fall and winter.

DWR uses a point system to evaluate the impact of reservoir operations on the quality of recreation at the site. The technique compares the average water surface area of the reservoir during the recreation season with the surface area at normal pool (spillway elevation). The ratio of recreation season surface area to normal pool surface area is then converted to a point value (0-50 points). Using this technique, the original operation schedule for Antelope Reservoir has a ratio of 0.96, corresponding to 49 points, while the revised operation (0.56 m^3/s) has a ratio of 0.95, or 48½ points. The alternative schedule (0.85 m^3/s) has a ratio of 0.92, or 47 points. These are all high values when compared to typical reservoir operations.

Ease of Access

Slightly increased summer drawdown would mean that the water surface of the reservoir would be a bit farther from campsites and other recreation sites than it was with the original operation schedule. There might be marshy conditions for a short time at a few areas with very low gradient. The original drawdown of about 0.7 cm per day would increase to about 1.2 cm per day, but the granitic soil around the lake would help minimize problems.

Moderate reservoir drawdown may be beneficial because it can create beach areas for sunbathers and swimmers. It can also provide easy foot access around the shore for anglers. On the other hand, too much drawdown encourages off-road vehicle owners to drive along the water's edge, resulting in added

costs for barrier construction and enforcement. This would be particularly true for the alternative schedule.

Drawn down 1.3 m, Antelope Reservoir acquires inviting beaches, submerged at full capacity.

Use of Recreation Facilities

The small drawdown increase in the proposed operation would not significantly affect use of any recreation facilities at Antelope Reservoir. Access from picnic and camp areas to the lake shore would not be affected. The Lost Creek Cove Boat Ramp extends to elevation 1 521 m and the water supply intake is near elevation 1 518 m. Neither the original nor the proposed operation schedules would draw the reservoir down to these levels because of the dry year criteria. Consequently, the proposed schedule should have no measurable effect on the amount of recreation use at Antelope Reservoir. On the other hand, a higher release schedule, such as 0.85 m^3/s, would cause reservoir levels to fall below the end of the boat ramp in December, January, or February about one year in three and would reduce use at those times.

Fish and Wildlife Production

The proposed higher downstream release and increased reservoir drawdown would cause a small reduction in mid-summer reservoir surface area. The surface area would shrink only about 1.2 ha more than with the original operation. This minor difference is due to the revised dry year criteria which anticipate low water years. A flow schedule of 0.85 m^3/s would reduce mid-summer reservoir surface area by an additional 8.9 ha over the original operation schedule. These losses of reservoir surface area would be compensated by somewhat greater increases in usable trout habitat in Indian Creek downstream to Taylorsville.

Eagles and osprey nest at Antelope Reservoir. Geese feed along the shoreline. The additional drawdown and reduced water surface might affect the success of these birds. However, the change is very small and both eagles and osprey nested successfully during the study period, so any impact probably is minor.

REQUIRED REVISIONS TO PERMITS AND LICENSES

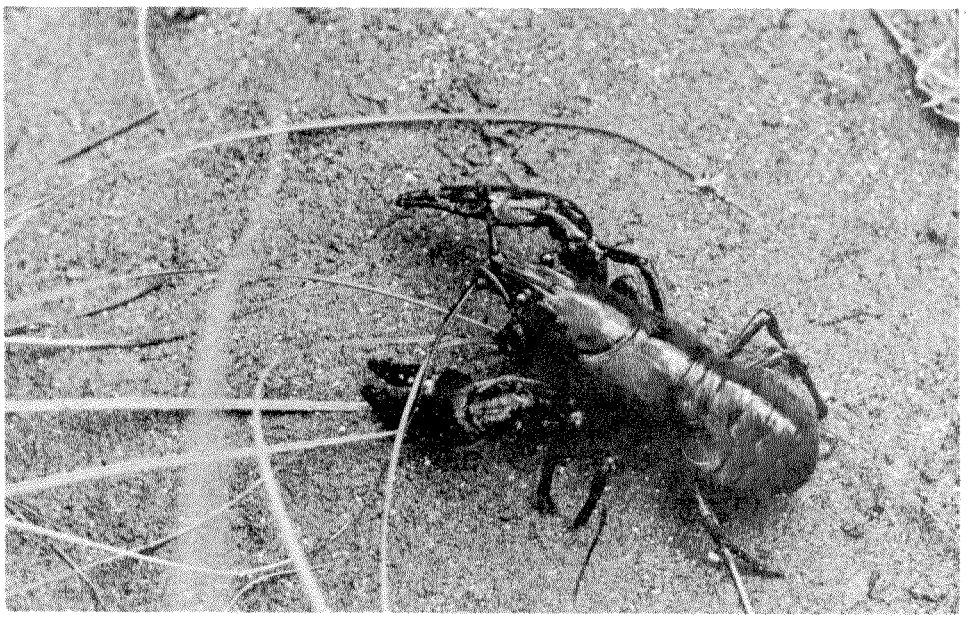
The USFS Use Permit for the operation of Antelope Reservoir generally describes the original operation schedule for the project. The proposed operation schedule would not violate provisions of this use permit in normal year operations, but it would conflict in dry years. Likewise, using the February 1 forecast of runoff conditions to reduce the release in exceptionally dry years would conflict with certain release provisions in the permit. Thus, the use permit should be revised to reflect the proposed release criteria.

The water rights agreement between DWR and PG&E requires that water released from storage in Antelope Reservoir be used only for streamflow enhancement in Indian Creek and the East Branch North Fork Feather River. The proposed operation schedule would not conflict with the provisions of this agreement and modification of the agreement is not required. As discussed earlier, the revised operation would benefit PG&E because it would slightly increase power production at the North Fork Feather River hydroelectric plants.

ACKNOWLEDGEMENTS

Too many people participated in the field work for the three-year monitoring program at Antelope Reservoir and Indian Creek to acknowledge them all. Most are named in the individual reports written for this study (see "References"). A few are mentioned here because of their major contributions to this effort.

Environmental Specialist Sharon Haines was involved in nearly every phase of the study and authored several of the reports. Her energy and hard work were invaluable. Student Assistant Emmett Cartier helped develop the recreation survey techniques in 1977 and conducted the surveys the first two years. Emmett took most of the photographs used in this report. His enthusiasm and willingness to work the long hours required to conduct the surveys set an example for those who followed. DFG Fishery Biologists Charles Brown and Nick Villa directed the fish population sampling and prepared annual reports on this important phase of the study. Environmental Specialist Gerald Boles conducted the water quality evaluation. Finally, the watermasters of the Indian Creek Service Area, particularly Joe Nessler, deserve appreciation for providing advice and cooperation throughout the study.



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APPENDICES A-G

APPENDIX A

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PLUMAS NATIONAL FOREST
Greenville, CA 95947

ADDRESS REPLY TO
DISTRICT RANGER
AND REFER TO
2530/2630

April 24, 1978

Mr. Ralph Hinton
Park and Recreation Specialist
Department of Water Resources
P.O. Box 607
Red Bluff, CA 96080

Dear Mr. Hinton:

Your proposed Indian Creek flow enhancement program is acceptable to us, subject to implementation of the low flow release schedule when a dry year is indicated by the annual D.W.R. March 1st runoff prediction.

We are, however, bothered that any gains made to improve the Indian Creek fishery could be negated (just when the full benefit is being realized) by the Department of Fish and Game's recurrent drain-poison program for Antelope Lake. We would like very much to see a stable aquatic ecosystem established in Antelope Lake, even if this would require its conversion from a trout fishery to a "warm water" fishery, with bass and bluegill replacing the trout. During treatment years, the resultant "drought" level flow reductions would dry-up most of the improved downstream habitat, and the available population of benthic insects used for trout food would be greatly reduced. The adverse effects of the lake-treatment program would be even worse on an otherwise improved Indian Creek trout habitat than they have been on the Indian Creek fishery in the past.

Several questions were raised by our Forest staff on the impacts of your increased flow program, viz.:

1. Sediment-flushing flows might be reduced, because of the increased amount of drawdown in Antelope Lake.

2. There is a possible, adverse effect from increased releases of anoxic, hypolimnial waters into Indian Creek. Odors and discoloration have been observed below the dam in mid to late summer in normal years. Sulfur dioxide seems to be coming from partly-decomposed bottom organic materials, as they are exposed to the open air.

3. There will be some aesthetic degradation of the lake environment along with the loss of some shallow water fingerling habitat, with reduced lake surface area.

We think that any deleterious effects from this project on flushing flows will be minimal. Flushing flows have already been greatly moderated by the Antelope Lake dam. Spring flows will still spill over the dam, and peak runoff should not be notably reduced. In an average year, the reservoir will take a little longer to fill, and the overflow period will be shortened by a week or two, because of the time needed to recover from the extra drawdown.

Increased late summer outflow will probably not result in a lengthened "septic" zone, beyond the presently affected reach of Indian Creek. The increased turbulence at the outflow point should quickly reoxygenate the released lake bottom water.

The extra drawdown required for the enhanced flow program will slightly reduce the useable lake surface, and some shallow water areas will be dried-up. Fishermen will find it easier to drive around the margin of the lake, using the exposed shoreline; such use will result in increased lakeshore disturbance and erosion. Visitor use levels should be unaffected by the small drawdown projected for the lake.

We feel that the net effect of this enhanced flow program will be (a) an improved Indian Creek trout fishery and (b) an increased recreation capacity for the Antelope Lake - Indian Creek portion of the Greenville Ranger District.

for JOHN M. BRYANT
District Ranger

Copy to: Forest Supervisor

United States Department of Agriculture
Forest Service
Plumas National Forest
P.O. Box 1500
Quincy, CA 95971

Reply to: 2350

Date: August 10, 1981

Mr. Ralph Hinton
Department of Water Resources
Box 607
Red Bluff, CA 96080

Dear Mr. Hinton:

We have reviewed the draft report for a revised operation for Antelope Reservoir dated July 1981 and have the following comments:

1. We agree with your proposed operation schedule and will work with you to revise the Special Use Permit.

2. Your report is silent concerning threatened and endangered species. The increased draw-down may be viewed as detrimental to bald eagles and ospreys by decreasing the surface area of the Reservoir available for food; conversely, both species have a mating pair with young birds this season at the Reservoir so the operating plan may not be all that adverse.

3. Your report does not mention motor vehicles going around the barriers when the Reservoir is down and driving along the shoreline. This is getting to be a major problem in the fall, winter and spring. This aspect of the additional draw-down is definitely detrimental as costs will be incurred extending the barriers further into the Reservoir and by having to increase the law enforcement effort with its resulting negative public reaction.

Your reports have provided interesting data of a kind that is all too seldom obtained. We look forward to receiving your final report.

Sincerely,

LLOYD R. BRITTON
Forest Supervisor

APPENDIX B

ANTELOPE RESERVOIR OPERATION CRITERIA

Release Criteria

Regulation Releases

Regulated releases from Antelope Lake include water both for Water Rights Entitlement and Project Releases. A Water Rights Entitlement is water that downstream users have rights to divert from Indian Creek. A Project Release is water for the enhancement of recreation, fish, and wildlife.

Regulated releases, made from the valve control house, are based on the reservoir water surface elevation each year according to the following release schedule.

TABLE 1

EXISTING SCHEDULES FOR REGULATED
RELEASES FROM ANTELOPE RESERVOIR

Storage Condition as of May 1	Regulated Releases in cfs											
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
		**	*	*	*							
Above Elev. 5002	20	20	10	10	10	10	10	10	10	10	10	20
		**	*	*	*							
Above Elev. 4998	15	15	5	5	5	5	5	10	10	10	10	15
		**	*	*	*							
Below Elev. 4998	10	10	5	5	5	5	5	5	5	5	5	10

TABLE 2

PROPOSED SCHEDULE FOR REGULATED
RELEASES FROM ANTELOPE RESERVOIR

Storage Condition as of June 1	Regulated Releases in cfs											
	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
	**	*	*	*								
Above Elev. 5002	20	20	20	20	20	20	20	20	20	20	20	20
	**	*	*	*								
Above Elev. 4998	10	10	10	10	10	10	10	10	10	10	10	10
	**	*	*	*								
Below Elev. 4998	5	5	5	5	5	5	5	5	5	5	5	5

* Or inflow, whichever is greater.

** Or inflow, whichever is greater unless prior approval has been obtained from the Districts having prior water rights.

NOTE: These criteria are reproduced from the Operation Manual, which does not use metric values, so they have not been converted.

APPENDIX C

SUMMARY OF OPERATION STUDIES FOR ANTELOPE RESERVOIR
(Drawdown in Metres)

	ACTUAL HISTORIC OPERATION			ORIGINAL OPERATION SCHEDULE[1]		
Year	September 1	Max. Year	-- Month	September 1	Max. Year	-- Month
1962	-	-		0.55	0.88	Sept.
1963	-	-		0.21	0.43	Oct.
1964	4.24[2]	10.21[2]	Dec.	0.61	1.13	Oct.
1965	0.03	2.65	Nov.	0.03	0.27	Oct.
1966	1.13	1.73	Nov.	0.98	1.65	Nov.
1967	0.15	0.40	Oct.	0.12	0.30	Oct.
1968	0.79	1.25	Oct.	0.82	1.28	Oct.
1969	0.24	0.52	Nov.	0.24	0.52	Nov.
1970	0.40	0.79	Oct.	0.40	0.79	Oct.
1971	5.55[3]	13.78[3]	Oct.	0.30	0.67	Oct.
1972	0.52	0.64	Oct.	0.70	1.04	Oct.
1973	0.85	1.25	Oct.	0.76	1.16	Oct.
1974	0.37	0.88	Nov.	0.21	0.73	Nov.
1975	0.49	0.85	Oct.	0.18	0.37	Sept.
1976	6.25[3]	15.51[3]	Oct.	1.31	2.01	Jan.
1977	10.15[3]	10.30[3]	Nov.	2.80	3.20	Nov.
1978	1.01	2.80	Jan.	0.55	1.34	Dec.
1979	0.88	1.65	Dec.	1.16	1.86	Dec.
1980	0.85	2.38	Jan.	0.46	1.07	Nov.
Average	1.99	3.97	Nov.	0.66	1.10	Oct.
W.S.Elev. (m)	1 522.62	1 520.63		1 523.95	1 523.52	
Surface Area (ha)	319	262		350	320	

1/ 0.56 m^3/s April to June, 0.28 m^3/s rest of year (see Appendix B).

2/ Initial filling of reservoir.

3/ Reservoir drained to remove non-game fish.

	PROPOSED OPERATION SCHEDULE[1]			ALTERNATIVE OPERATION SCHEDULE[2]		
Year	September 1	Max. Year	Month	September 1	Max. Year	Month
1962	1.04	1.55	Sept.	1.55	2.32	Sept.
1963	0.58	1.19	Oct.	1.01	2.93	Feb.
1964	1.04	2.26	Nov.	1.62	3.66	Nov.
1965	0.30	1.16	Feb.	0.73	3.08	Feb.
1966	1.62	3.08	Nov.	1.46	2.13	Nov.
1967	0.34	1.19	Dec.	0.55	2.38	Jan.
1968	1.28	2.44	Dec.	1.95	4.30	Dec.
1969	0.52	1.46	Nov.	0.94	2.62	Nov.
1970	0.82	1.68	Oct.	1.25	2.62	Nov.
1971	0.52	1.34	Oct.	0.73	2.65	Jan.
1972	1.16	2.10	Nov.	1.80	4.05	Feb.
1973	1.19	2.07	Oct.	1.83	3.29	Oct.
1974	0.61	2.16	Jan.	1.01	4.08	Feb.
1975	0.49	1.62	Feb.	0.91	3.29	Jan.
1976	1.31	2.01	Jan.	2.56	2.90	Oct.
1977	2.53	2.90	Nov.	2.74	3.14	Nov.
1978	1.01	2.93	Jan.	1.40	4.94	Jan.
1979	0.98	1.77	Dec.	2.19	2.50	Nov.
1980	0.88	2.38	Dec.	1.31	4.27	Jan.
Average	0.96	1.96	Nov.	1.45	3.22	Dec.
W.S.Elev. (m)	1 523.65	1 522.65		1 523.16	1 521.39	
Surface Area (ha)	349	318		334	283	

1/ 0.56 m^3/s year-round (see Appendix B).

2/ 0.85 m^3/s year-round.

APPENDIX D

SUMMARY OF INDIAN CREEK TROUT
POPULATION ESTIMATES, 1977-80 1/

BROWN TROUT

Year	Age of Fish <1 (60-129 mm)	1-2 (130-229 mm)	2-3 (230-300 mm)	>3 (300-400 mm)	Total
1977	123	66	9	2	200
1978	90	32	18	2	142
1979	668	41	3	1	713
1980	80	228	15	2	325

RAINBOW TROUT

Year	Age of Fish <1 (50-129 mm)	1-2 (130-199 mm)	2-3 (200-279 mm)	>3 (280-380 mm)	Total
1977	3	6	1	0	10
1978	19	5	3	1	28
1979	17	6	8	1	32
1980	89	36	12	2	139

1/ Annual population estimates at six permanent stations totaling about 280 m of upper Indian Creek (1.5 percent).

APPENDIX E

RECORD OF TROUT STOCKED IN
INDIAN CREEK, 1950-80 1/

Year	Species	Size	Number
1950	Rainbow	Fingerling	39,300
1951	Rainbow	Fingerling	14,820
1951	Rainbow	Catchable	2,220
1952	Rainbow	Catchable	4,110
1952	Rainbow	Fingerling	1,008
1953	Rainbow	Catchable	4,000
1953	Rainbow	Fingerling	20,000
1954	Rainbow	Catchable	9,540
1955	Rainbow	Catchable	11,120
1955	Rainbow	Fingerling	3,885
1956	Rainbow	Catchable	11,013
1957	Rainbow	Catchable	9,989
1958	Rainbow	Catchable	10,013
1959	Rainbow	Catchable	8,197
1960	Rainbow	Catchable	6,734
1961	Rainbow	Catchable	4,977
1962	Rainbow	Catchable	6,010
1963	Rainbow	Catchable	4,633
1963	Eastern Brook	Catchable	812
1967	Brown	Fingerling	2,500
1971	Rainbow	Catchable	108
1973	Brown	Fingerling	5,250

1/ DFG, Region 2 files.

APPENDIX F

RECORD OF FISH STOCKED IN
ANTELOPE RESERVOIR, 1977-80 1/

Year	Species	Size	Number
1977	Rainbow	Catchable	15,000
1977	Rainbow	Subcatchable	69,000
1978	Rainbow	Catchable	20,555
1978	Rainbow	Fingerling	230,000
1979	Rainbow	Catchable	15,000
1979	Rainbow	Subcatchable	8,000
1979	Rainbow	Fingerling	245,980
1980	Rainbow	Catchable	13,440
1980	Rainbow	Subcatchable	19,920
1980	Rainbow	Fingerling	150,000
1980	Channel Catfish	Catchable	6,050

1/ DFG, Region 2 files

APPENDIX G

MONTHLY RECREATION USE AT ANTELOPE RESERVOIR
1974-80 (Recreation Days) 1/

Month	1974	1975	1976	1977	1978	1979	1980	Percent
January	0	0	0	0	0	0	700	0.1
February	0	0	0	0	0	0	2,100	0.2
March	5,300	0	0	0	0	2,500	7,000	1.5
April	30,300	5,000	3,300	0	0	13,000	9,100	6.4
May	39,600	13,600	21,400	2,100	20,300	29,200	35,300	17.0
June	32,200	23,600	23,300	3,700	12,400	57,600	35,900	19.8
July	19,400	19,500	19,800	2,200	7,500	42,600	45,500	16.4
August	24,800	13,700	6,900	2,200	5,000	51,400	43,800	15.5
September	15,300	9,800	3,900	2,500	5,500	41,700	23,300	10.7
October	10,900	11,100	1,600	2,000	19,600	13,700	15,400	7.8
November	0	4,000	0	0	11,700	13,200	3,000	3.4
December	0	0	0	0	1,200	8,600	1,900	1.2
Totals	177,800	100,300	80,200	14,700	83,200	273,500	223,000	100.0

1/ Reported by USFS, Plumas National Forest

CONVERSION FACTORS

Metric to Customary System of Measurement

Quantity	Metric Unit	Multiply by	To get customary equivalent
Length	millimetres (mm)	0.03937	inches (in)
	centimetres (cm)	0.3937	inches (in)
	metres (m)	3.2808	feet (ft)
	kilometres (km)	0.6214	miles (mi)
Area	square metres (m^2)	10.764	square feet (ft^2)
	hectares (ha)	2.4710	acres (ac)
	square kilometres (km^2)	0.3861	square miles (mi^2)
Volume	cubic dekametres (dam^3)	0.8107	acre-feet (AF)
Flow	cubic metres per second (m^3/s)	35.315	cubic feet per second (ft^3/s)
Mass	kilograms (kg)	2.2046	pounds (lb)
	kilograms per hectare (kg/ha)	0.8922	pounds per acre (lbs/ac)
Velocity	metres per second (m/s)	3.2808	feet per second (ft/s)
Concentration	milligrams per litre (mg/l)	1.0	parts per million
Electrical conductivity	microsiemens per centimetre (µS/cm)	1.0	micromho per centimetre
Temperature	degrees Celsius (^oC)	(1.8 x ^oC) + 32	degrees Fahrenheit (^oF)